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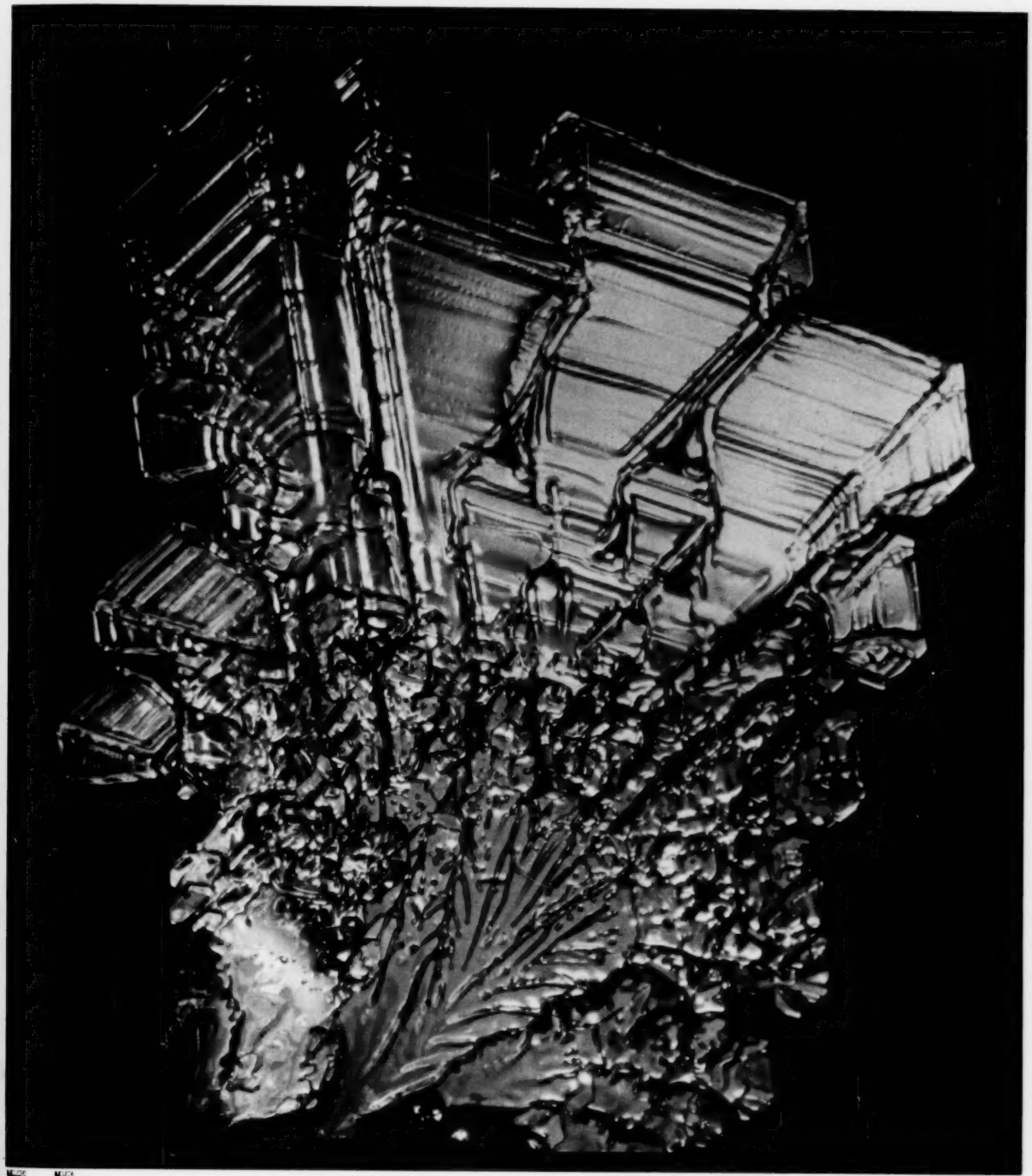

DEPARTMENT OF THE ARMY, CORPS OF ENGINEERS

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Comments on topics in this publication are invited. Send to:
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Cover: Microscopic study of frost formation, such as the pattern of this magnified hoarfrost crystal, helps in year-round research covering ice growth and other environmental characteristics in permafrost regions. See story on page 28.

An artist's concept of the Earth Resour Technology Satellite in o

Resource Management:

by Dr. Arch B. Park
Chief, Earth Resources Survey
National Aeronautical and Space Administration

Space imagery reflects changing characteristics of earth's water, and provides unique data for resource managers.

The practice of divining water through a hand-held rod has become quite a remote art today. So remote that, in effect, we actually do it from outer space. But instead of laboriously planting one foot in front of the other in the former tradition, our satellite overflies every point on earth between 81° north and 81° south at least once every 18 days.

Acquiring 10,000 square miles on a single frame of space imagery, the remoteness of our satellite enables it to look at vast areas of the earth in one fleeting glance. You can be sure capabilities of such an advanced working tool have not escaped the eyes of our water resource planners and managers who are striving to meet steadily increasing demands for more water by urban, agricultural and industrial users.

The theory of remotely sensing the location and characteristics of our natural resources has been a part of NASA's Earth Resources Survey Program for some time.[1] But the actual survey is just beginning with this year's launching of its Earth Resources Technology Satellite (ERTS) and will be reinforced in 1973 with the scheduled orbiting of Skylab, a manned space station.

Both of these satellites will gather data that can be put to direct use by all our resource planners and managers almost as quickly as it is collected. The following examples depict the variety of problems to which remotely sensed space data will be applied.

For instance, the Metropolitan Maryland-District of Columbia-Virginia urban land complex adjoins an equally complex Chesapeake Bay hydrodynamic system. The latter system is an estuary receiving fresh water flows that bear sediment loads from a number of rivers. Upon entering this estuary, these fresh water inflows are subjected to the new environment of the estuary by the influence of tides, salt water and other factors which act to alter both the flow patterns and sediment distribution of the inflows.

The result is a complex mixing of sediment-laden fresh and salt water with relatively clear salt water. Not only do the tides change the direction of estuary flow daily, but seasonal fluctuations periodically increase or decrease the volume and turbidity of the inflow from the rivers.

The hydrodynamic characteristics of ocean and estuary waters constantly change in flow patterns, current boundaries, sediment load distribution, sediment dispersion and biological content. Therefore, when data collected over a period of time are used to reconstruct the conditions existing at any one instant these characteristics are probably distorted.

Sometimes the scale of such phenomena is just too large to allow accurate reconstruction of the conditions being studied. This may be due to the inaccuracies of sampling, the dynamic nature of the problem or the inability of obtaining an overall view of that particular environmental system. So the use of high altitude aircraft and satellite imagery may provide the means of recording these dynamic phenomena instantaneously, capturing the characteristics of a total estuarine system.

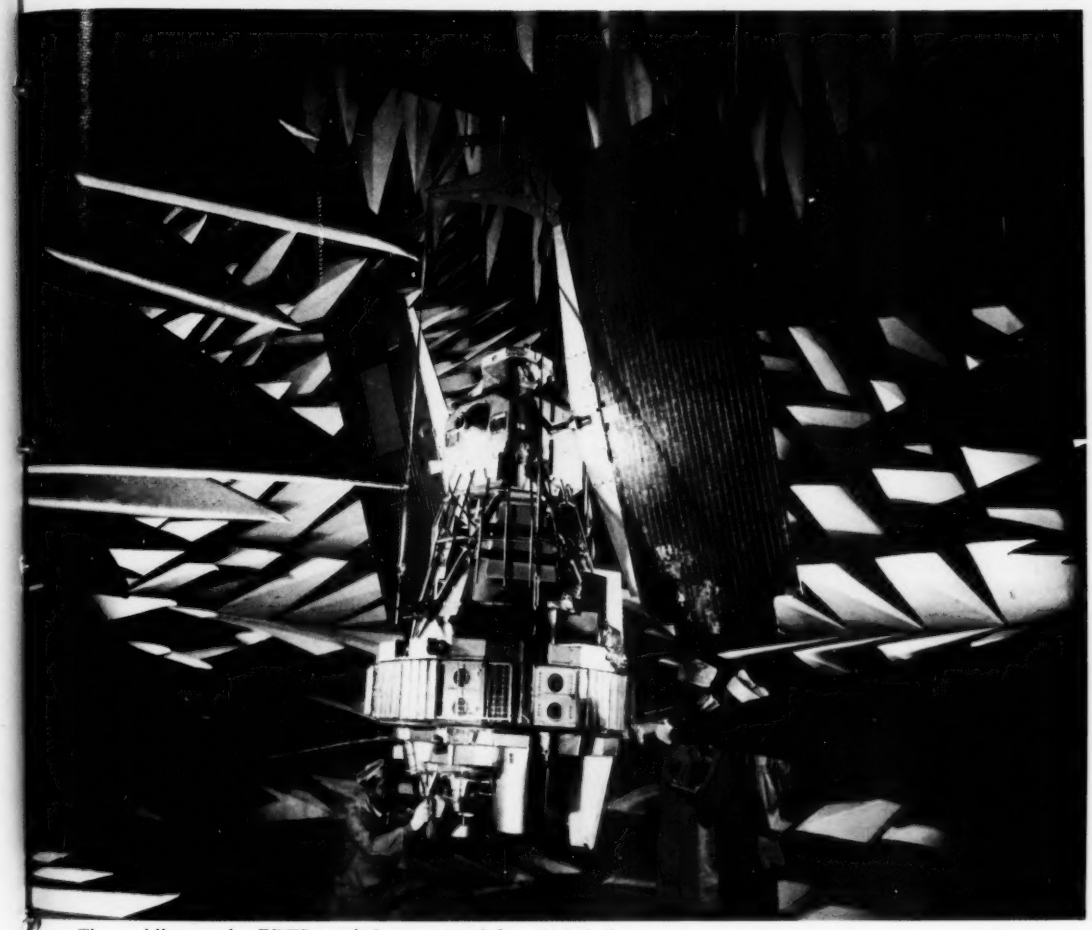
A coordinated regional test of remote sensing systems is being developed for the Chesapeake Bay area to investigate this exciting prospect. Studies will be undertaken to test the feasibility of delineating currents, flushing actions, littoral drift patterns and pollution concentrations. There will also be attempts to map land-use patterns, wetland areas, geological formations and the hydrologic characteristics of this area.

To assure maximum benefits, these studies will be linked with such ongoing research as the coordinated NSF-RANN (National Science Foundation-Research Applied to National Needs) program for the Chesapeake Bay and the Corps of Engineers' Chesapeake Bay Study. Maryland will use this program to develop techniques for applying satellite imagery to the resource management tasks of a State Government.

The most important water management activity based on the data to be collected could very well be its use in flood forecasting. This is especially so where there are large artificial impoundments, where even a remote possibility of sizeable rainfall exists or where snowfields persist into warmer months when rapid melt will occur. The use of satellites to relay such data from remote ground sensing stations to a central control point may permit a type of monitoring not feasible before.

The New England Division of the Corps of Engineers is testing this concept with ERTS in the hope of developing a faster, more economical system of transmitting early flood warnings and predicting availability of regional water supplies.

1. Charles J. Robinove, "Perception Via Satellite," *Water Spectrum*, Vol. 2, No. 1 (Spring 1970), pp. 14-19.



The paddles on the ERTS are being prepared for a "shake" test in a NASA test chamber prior to launching.

The Coastal Future

As urbanization continues into the year 2000, vast super cities have been envisioned, spreading along the coasts for hundreds of miles. As this occurs, estuaries and adjacent coastal areas will be used by many more people in different ways. Already the growth of these population centers has generated pollution problems of great magnitude and has severly affected shoreline features in the coastal zone region. Better understanding of the basic environmental processes of this zone, as well as man's interaction — pollution or the building of shoreline structures, for instance — with these processes is urgently needed.

In their efforts to solve these problems, coastal engineers and scientists require information about what is happening along the shoreline where the land is under constant attack by the forces of nature. Wind, waves, currents, and tidal forces continuously reshape the coastlines, where man is seeking to achieve equilibrium and maintain stability. Many buildings, beaches, roads, and shore-protection structures have failed because the designers had insufficient data concerning the natural forces involved.

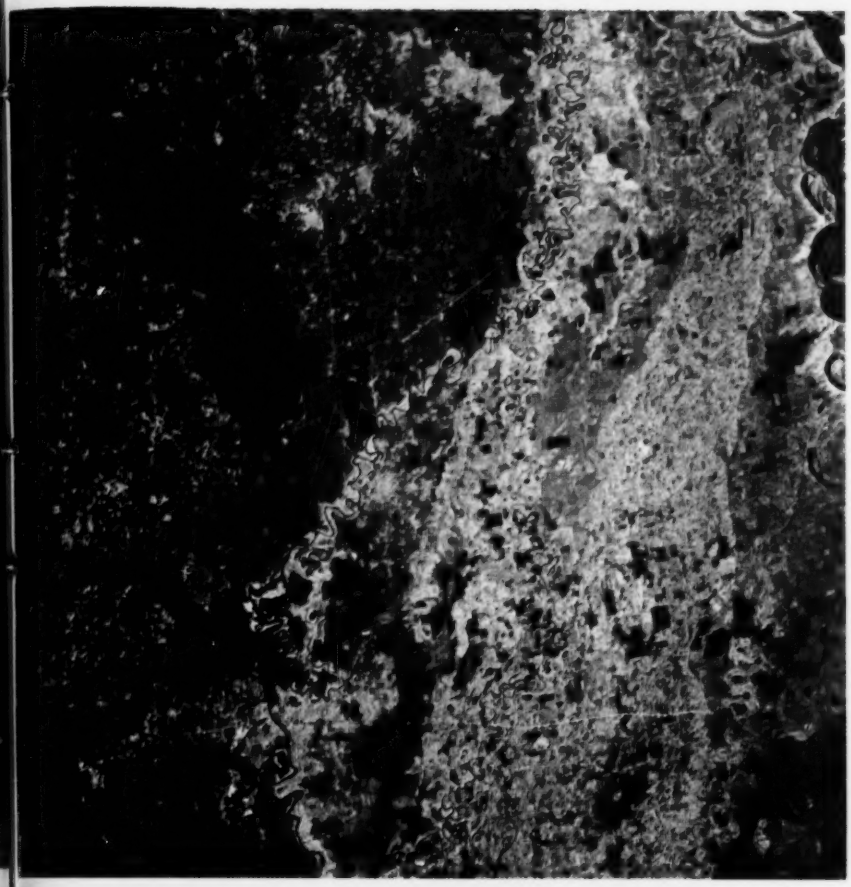
Even now, when the need for such information is widely acknowledged, the coastal engineer is handicapped because such information is rarely available. At present, conventional methods of collecting the required long-term information at even one nearshore site take a long time.

So the Corps of Engineers and North American Rockwell Corporation will investigate the ability of spaceborne sensors to record useful information in the coastal environment. The specific goal of this study is to develop additional research information on coastal processes for the Corps, based on remote sensing.

The four study elements being researched are: (1) nearshore currents, (2) estuarine exchange, (3) seasonal river discharges, and (4) waste dump dispersion. Since these elements are related by the observable phenomena which define them, it is felt that the basic set of remote sensing data types can be applied to all the study elements. The study objectives can best be fulfilled by going from the detailed to the general. For this reason, test cells are being selected along the California coast where concurrent surface data and aircraft measurements may be made in conjunction with ERTS overflights.

An Apollo 9 photo of southern California's Imperial Valley shows the wide field of view possible from space. This fertile Valley's croplands, represented by the reddish rectangles, are sandwiched between the blue waters of the Salton Sea and the noticeable change in color at the Mexican border, which indicates less use of irrigation. To the right are the Colorado Desert, the southern San Bernardino Mountains and the faintly discernible Colorado River flowing south toward the Gulf of California.

The absence of reddish tones on this color infrared photo of the Lake Mead National Recreation Area denotes an extremely dry terrain. Such relatively inaccessible areas illustrate the obstacles confronting timber and rangeland managers in making inventories of wildland resources and estimating their vulnerability to destruction by fire. Hoover Dam, which forms Lake Mead from the Colorado River, is marked by an arrow near the center. Boulder City, Nevada, is to the Dam's lower left.



Astronauts captured this flood on the Ouachita River in Louisiana and Arkansas in varying hues of pink following heavy spring rains. The color gradients relate to the differences in flood depths and the changing nature of the flooded terrain from point to point. Close study of such photos may aid in preventing future floods or reducing the amount of damage. The meandering oxbows of the Mississippi River, which the Ouachita joins farther south, are visible at the extreme right.

This infrared image of the Pacific Coast border area between California and Mexico converts populated areas into shades of gray. San Diego appears just below center on the coast and Tijuana, Mexico is represented as a smaller gray area below the southern end of San Diego Bay. The Santa Ana Mountains run from top to bottom of the photo farther inland.

Prospecting for Hidden Water

The Apollo 9 flight brought back space photographs that hinted at new water sources undetected from the earth's surface. Geologists of the U.S. Geological Survey (USGS), examining photography taken over central Alabama by the Apollo 9 astronauts, observed lineations that appeared as traces of faults on geologic maps. One of them remarked that, although several man-months were required to map one specific fault with traditional field techniques, the same fault was delineated in a few minutes on near infrared high-altitude imagery.

These photographs include high altitude views of our most visited national park — The Great Smoky Mountains. As the number of visitors increases every year, additional supplies of good quality water are needed for restrooms and drinking fountains at the picnic grounds and camp sites. Although ground water in this area (eastern Tennessee and western North Carolina) is of good quality and cheap to develop, most of the local wells produce only a few gallons per minute. The exceptions are wells that intercept rock faults and produce up to several hundred gallons of water per minute.

Geologic maps of high quality have been available for this national park for a long time, and all large faults have been mapped. However, the rock formations are covered by soil in many areas so that the exact locations of many smaller fault segments are unknown and overlooked. But the anticipated utilization of Skylab sensors will eventually enable USGS to pinpoint these locations through infrared imagery.

After using the new Skylab data to take care of the needs of visitors to the Great Smokies, USGS plans to employ Skylab's sensors for groundwater prospecting in other regions of heavily wooded mountainous terrain.

In the arid regions of the southwestern United States, Dr. Monem Abdel-Gawad of the North American Rockwell Corporation is directing a similar program to locate surface and subsurface stream "captures" and watercourse changes caused by shifts in the earth's crust. As in the USGS program for the Great Smokies, the team of "prospectors" from North American Rockwell will be seeking and studying lineations on the imagery from space.

Basinwide Imagery

The ability to photograph wide swaths of the earth's surface in one pass will provide many benefits to areas such as the Lake Champlain Basin. Lake Champlain is centered in a natural basin draining parts of Vermont, New York State, and the Province of Quebec, Canada. Storied for its spruce and fir forests, its blue waters, winter and summer sports, and a historic role in three wars, the Lake Champlain Basin has often been presented as an idyllic rural setting where people work and play within a healthy and aesthetically satisfying environment.

Two interrelated problems are now spreading through the region, both resulting from conversion of rural to urban land uses: increasing water pollution and land degradation.

State and local officials, along with associated planning agencies, are looking to the University of Vermont to provide answers to these problems. A team of geographers, geologists, engineers and biologists, headed by Dr. Aulis O. Lind, is presently dealing with a host of environmental problems in the Lake Champlain Basin and is formulating programs to not only alleviate degradation of land, air and water, but also to develop the basin's economic resources.

Dr. Lind writes, "...there seems to be little doubt that ERTS imagery will provide a range of information which would otherwise be either difficult or impossible to obtain by surface observations alone."

The resource program includes locating subsurface water routes and collection areas. The additional water so located can be utilized for residential and commercial purposes. It is equally important in the zoning of land, so that ground water quality is not impaired by residential septic tank discharges.

In the lake itself, the program involves early warning, identification and treatment of toxic algal blooms. Areas of heavy sedimentation and urban and industrial pollution are identified in large part through lake turbidity patterns, which can best be determined through remote sensing.

The wave energy patterns of Lake Champlain's waters are being incorporated into the planning of manmade beaches near the city of Burlington on the Vermont side of the basin. Wave movements can be utilized in building beaches; conversely, a misplaced beach would soon be eroded.

Finally, the imagery that will assist ground water studies will also be valuable in prospecting for sand and gravel deposits of economic significance. Dr. Lind thinks that, through the analytic process, other useful applications of ERTS imagery will emerge.

For all parts of the basin program, usage of ERTS imagery falls into two discrete categories: change detection through periodic viewing of the same scene over time, and capturing a view of the lake and its basin in just a few images, so that major spatial relationships and associations can be more easily analyzed.

Penetrating Ecuador's Remote Areas

The future applications of ERTS imagery are by no means limited to the geographical boundaries of the United States or even those of North America as satellites circle the entire globe. For example, the South American nation of Ecuador faces some problems quite similar to those in the United States.

The recent discovery of extensive oil fields in the high valleys on the eastern slopes of the Andes has led to un-

precedented road-building activity in the northern provinces. And the increasingly rapid rates of colonization and cultural development along these new roads led the National Planning Council *(Junta Nacional de Planification)* at Quito to predict that services and industries will quickly follow as some of the land-use patterns in these northern provinces change from rural to urban.

In addition, says the council, existing forests will soon succumb to cultivated fields. Since the eastern Andean slopes are constantly awash under intensive rainfall, a rational and carefully developed program must be designed to prevent destruction of forest zones and loss of soils while maintaining a balanced use of the land.

Deforestation, increased cultivation, and overgrazing under the constant washing rains have all combined to produce rapidly deteriorating soil. Although the soils of the eastern Andean slopes are a key consideration in resource management and cultural activities, very little detail is known about them.

Surface studies are prohibitively slow and tedious because of the steep topography, the rains, and the lack of access into remote areas. Yet the data from such studies are imperative to any realistic planning effort. Obtaining the data is one problem. An additional problem is that if the data were not obtained rapidly, planning would come too late — after actual developments take place on the land itself.

Dr. Nestor Vega Moreno, technical director of the National Planning Council of Ecuador, and Lt. Col. Carlos A. Espanoza Romero, of the Institute of Military Geography, have devised a program which they believe will limit haphazard colonization and land usage by providing sufficient planning information within the time limits. They plan a major surface study combining the personnel and abilities of the Air Force, other governmental agencies, the oil companies and international missions.

The crux of the program will be to compare these findings with the data received from ERTS. The frequency of ERTS coverage will lessen the problems presented by cloud cover over the rain forests. The ERTS data will be incorporated into the program only during the five months of the year when cloud cover is minimal.

This program will cover a 180-mile-long area running north-south along the eastern Andes and including the ridges, slopes and lowlands. Once the signatures of ecological characteristics are identified for the limited ERTS test area, the findings can be extended to the vast, remote areas where knowledge is scant or even nonexistent. ERTS imagery should make a significant contribution to future Ecuadorian national policy and decision-making.

Sensing Watershed Changes

Within the Detroit metropolitan region, Oakland County represents one of the most rapidly growing population areas in the United States. Oakland County is important, if not unique, in another respect. More than 1,100 lakes lie within its boundaries. These lakes are vital to the economic and social well-being of the area — as a source of water for people and industry, as well as for fishing, swimming, and boating. They are connected by rivers and canals to form a vital transportation system. Their aesthetic values are beyond measure for tourists and home owners.

But a lake is one of the most temporary features in nature. From the moment of its formation its banks start weathering, vegetation begins to push out toward the middle from the shoreline, and sediment begins settling to the bottom, filling it in. This aging process is often called eutrophication and, under natural conditions, extends over thousands of years.

Unfortunately, the life expectancy of a body of water can be shortened considerably in areas of dense human activity. This "cultural eutrophication" results when domestic, industrial, and agricultural sources enrich the water with phosphates and fertilizers. These nutrients accelerate the aging process by increasing productivity to the level whereby a small inland lake may become choked with weeds within three years.

The team working on staving off this decaying process in Oakland County combines the efforts of two types of scientific groups, commercial and non-profit, to bring together almost 25 years of lake euthrophication studies and multivariate data processing techniques. Aircraft photos of the 1,100-plus lakes have already been analyzed. The continual monitoring of ERTS data will determine where immediate endeavors and expenditures can best be applied to preserve and restore the lakes to their formerly pristine conditions.

A Michigan scientist, Mr. Phillip E. Chase of the Bendix Aerospace Systems Division, is concerned over the rapidity with which an increasing number of lakes are aging, thus providing diminished benefits and lowering the quality of life for people living in or visiting southeastern Michigan.

This aging process creates subtle color changes in the water and the rapidity of water color change in built-up areas may be more easily detected by satellite sensing than by aircraft. Mr. Chase explains why: "Although satellites that appear repetitively are just as limited by weather, due to cloud obscuration, they are not limited in terms of safety as in the case of aircraft. A satellite passes regularly and predictably over remote regions as well as areas near and within a metropolitan complex. The satellite's advantage over aircraft in passing over remote areas is obvious; its advantage in areas more readily accessible to aircraft lies in the rapidity of color change detected in lakes within built-up areas." The color changes generally reflect algae blooms of a few days' duration, seasonal growth of aquatic rooted plants, and inflow of suspended sediments from the surrounding landscape.

ERTS imagery will eventually realize the full potential hinted at by this computer printout map. This map illustrates how varying ground cover reflections can uniquely identify the infrared "signature" of different soils, minerals and vegetative growth. The computer was taught to recognize these as separate responses to the different parts of the color spectrum presented on an infrared image photo. A dose of human interpretation and addition of known surface data completed the map, which is useful in the hydrologic analysis of ground covers.

In natural aging, lakes fill in from the edges, first becoming ponds and then, as the process continues, becoming marshes or swamps.[2]

another region of high pond and lake density is the southern High Plains area, which extends from the panhandle of Texas into New Mexico. Cotton and grain sorghum production here rank among the highest in the United States.

Last year, however, Dr. William T. Miller and his associates of the Lubbock Campus of Texas Tech University reported that 70,000 irrigation wells are rapidly depleting the underground water supply of the region's major acquifer (the Ogallala Formation). This loss of underground water strongly threatens the regional economy.

Other water resources must be sought in this region, which contains more than 20,000 lakes ranging from under an acre to 500 acres in size, with a distribution of about one per acre. These lakes may provide the needed water, but there is one problem: The lakes aren't there all the time.

These intermittent lakes can most simply be described as water accumulated in closed basins (playas) after each rainstorm. The eventual loss of water from these playas occurs from evaporation, irrigation, and seepage into the ground to recharge the underlying aquifer fed by the Ogallala fracture. To date there has been no serious effort to measure this loss.

In view of the widespread economic consequences resulting from depletion of the Ogallala fracture, these as-yet-unused water resources must be inventoried. But the sheer physical size of the problem (35,000 square miles) makes conventional means extremely costly and time-consuming.

Dr. Miller, with a team of professional meteorologists, geologists, soil scientists, hydrologists and civil engineers, is planning to utilize new techniques based on the availability of sequential remotely sensed imagery to monitor the playa sites. Conventional ground surveillance instrumentation and techniques will be combined with the repetitive and spatial monitoring features of ERTS. The combination of satellite and ground surveillance will evaluate parameters affecting the water budget in the playa system, overcoming previous limitations and permitting contemporary ground studies to be undertaken on a continuing basis.

2. A lake is defined as a body of water large enough and deep enough so that rooted vegetation is limited to the shallower areas where sunlight reaches the bottom in sufficient intensity to permit growth. A pond may be large or small, but is shallow enough to support rooted vegetation over all or most of its area. A marsh is defined as a habitat covered by emergent nonwoody plant growth. A swamp is dominated over most of its area by emergent woody vegetation.

new Orleans' Lake Pontchartrain area, while famed for its recreational opportunities and romantic novel settings, also supports an inland commercial fishing industry. Furthermore, emergent vegetation nearshore feeds and lodges large muskrat colonies, providing income to local trappers. The importance of this fur industry to the "Pelican State" cannot be overestimated. For years, Louisiana has produced more muskrat furs annually than Canada, and the furs from the Lake Pontchartrain area comprise a large percentage of this total.

Over the years, various engineering projects involving the ecology of Lake Pontchartrain have been proposed. These changes include a twin 24-mile-long bridge across the center of the lake, dikes to control floods and pollution, and construction of a major airport on the lake's shore. These developments will influence — to an as yet unknown degree — the turbidity, vegetation, chlorophyll concentrations, water depths and currents, which in turn are determinants of fish breeding grounds and food cycles in the lake.

At Tulane University, a group of chemists, engineers and biologists, headed by Mr. John V. Hidalgo, have been actively pursuing a number of projects dealing with the entire delta region's resources. The Tulane scientists plan to incorporate the repetitive features of ERTS and the broader infrared coverage of Skylab into ongoing programs for managing existing developments and assessing the effects of proposed engineering changes. The goal of maintaining and improving the economic base through enlightened management policies for Lake Pontchartrain becomes more realistic with the addition of satellite reporting.

these few examples do not begin to exhaust the potential of satellite remote sensing, but they do point up the value of this new tool. Today man's numbers are so large that land, food, minerals, and air — as well as water — must be considered as finite resources. Therefore, man's ability to manage these resources effectively will, to a large degree, determine the standard of living of future generations.

Remote sensing will provide the environmental and resource information which cannot be effectively gathered by traditional survey methods; and planners and managers who must make decisions that affect us all can expect useful observations from the newly available vantage point of outer space.■

Sidney Lanier

No.1 LAKE ATTRACTION

by Robert L. Solheim

Out of the hills of Habersham,
Down the Valleys of Hall,
I hurry amain to reach the plain,
Run the rapid and leap the fall,
Split at the rock and together again,
Accept my bed, or narrow or wide,
And flee from folly on every side,
With a lover's pain to attain the plain,
Far from the hills of Habersham,
Far from the valleys of Hall

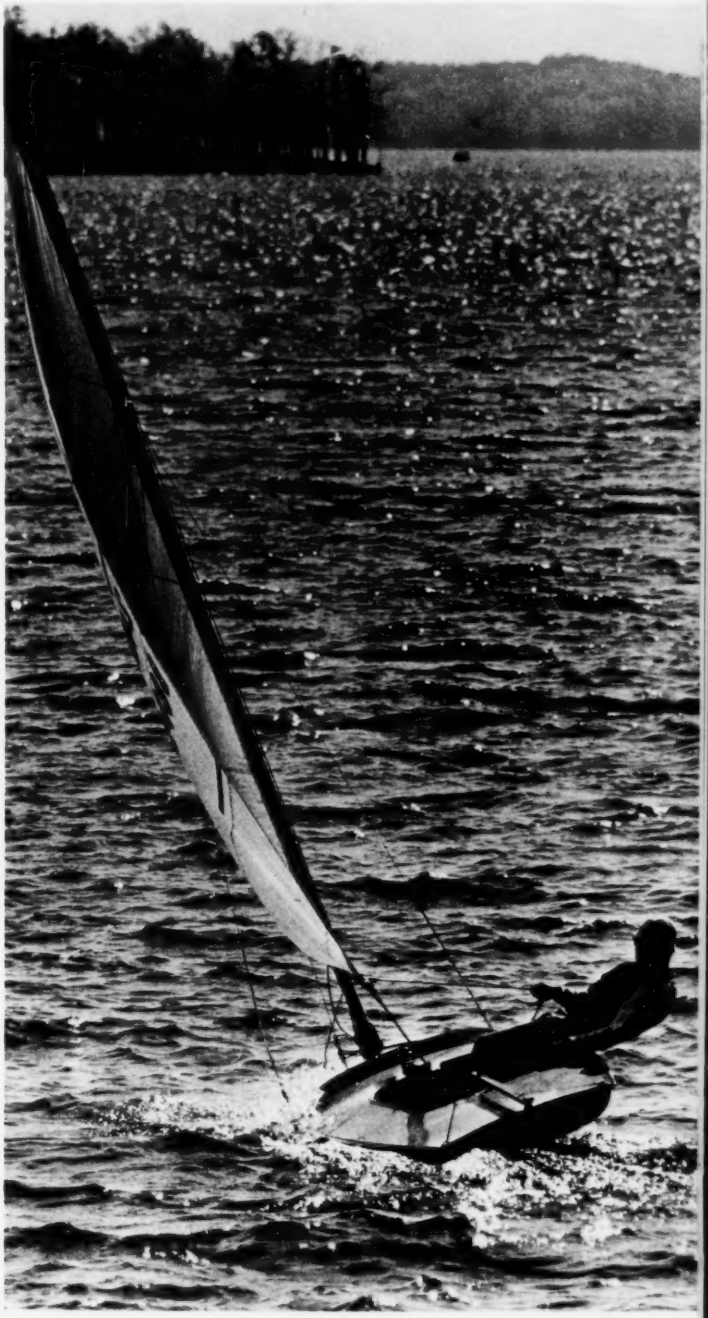
This verse from "The Song of the Chattahoochee" by Sidney Lanier describes Georgia's scenic Chattahoochee River, which, on its way to the Gulf of Mexico, pauses to form a 38,000-acre lake. This Lake, on the course of the Chattahoochee River, was named for the famed Georgia poet, Sidney Lanier, who, as was said by James Edward Oglethorpe, "touched life at many points." During Lanier's short life (1842-1881), he used his many talents and diverse character traits in producing poems of the South. In addition to his role as poet of renown, he also touched life as a soldier, clerk, lawyer, teacher, musician, and novelist.

Sidney Lanier had many varied interests, and his namesake, Lake Sidney Lanier, satisfies the many different interests of the millions of people who visit this recreation playground of the southeastern States. During July 1971, the person who made the 100-millionth visit was officially welcomed, giving Lake Sidney Lanier a record of more recreation visitations than any other Corps of Engineers project in the United States. Let us examine facts and values that can give an area that much appeal.

The Lake is formed by Buford Dam, an upstream project on the Chattahoochee River, and provides storage for flood control, power, and regulation of this river. The construction of Buford Dam, 35 miles northeast of Atlanta, Georgia was completed in 1957, and immediately upon formation of the Lake, the project started attracting visitors. Because of the hilly terrain, they can enjoy the view of 540 miles of shoreline surrounding this body of water. It extends from the dam to 44 miles up the Chattahoochee River, with a secondary arm extending 19 miles up the Chestatee River. In the vicinity of the dam, the Lake has depths of 160 feet with large open areas for water recreation. The rugged terrain of shoreline and the many islands in the Lake are heavily covered with a mixture of oak, elm, sycamore, dogwood, hickory and several varieties of pine. Because of the rolling terrain, many vista areas overlook the water's glistening surface and the numerous wooded islands and peninsulas.

The author is Chief of the Recreation Resource Management Branch, Construction-Operations Division in the South Atlantic Division, Corps of Engineers.

On good sailing days more than 1,000 sailboats cruise and race over Lake Lanier waters.



Some 38,000 acres of water surround the Islands of Lake Lanier.

Accessibility to visitors is another plus. A well developed network of roads encircles the Lake with seven highway crossings over the main body of water. A four-lane divided highway parallels the eastern shore of the Lake and junctions with Interstate Route I-85, which extends into Metropolitan Atlanta. Another expressway is under construction on the west side of the Lake, and it will also connect the Lake area with the city of Atlanta.

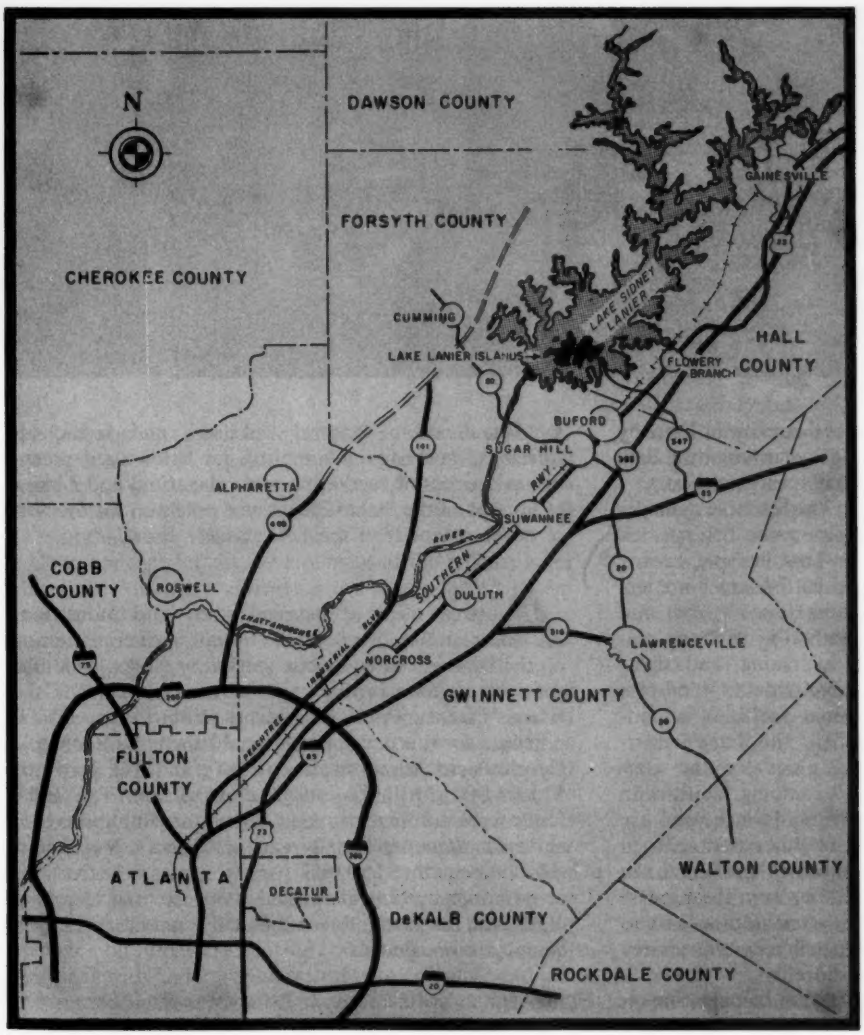
On the 18,000 acres of project land surrounding the Lake, 68 recreational sites have been developed for use by the public. Fifty-three of these recreational areas are operated and maintained by the Corps of Engineers through the resource manager, Cecil Patterson, and his staff.

In these 53 recreation areas, the Corps of Engineers has developed facilities for picnicking, camping, sightseeing, fishing, swimming, boating and the various other recreational uses enjoyed by the public visiting this Lake. Fifty-three boat launching ramps have been constructed by the Corps with adjacent parking areas capable of accommodating over 3,000 vehicles. Picnicking is very popular at the Lake and the Corps maintains 750 picnic tables in 37 different picnic sites. These picnic areas have been located at sites where a view of the Lake and its many activities can be enjoyed together with a picnic lunch. Campers visiting the Corps maintained areas will find the majority of the 450 camp sites located close to the Lake shore. While no beaches have been constructed by the Corps, there are numerous natural beaches formed in protected coves where the public can safely enjoy swimming in the Lake.

The fifteen recreation sites that are not operated by the Corps are leased for operation and maintenance to Lake Lanier Island Development Authority, Georgia State Highway Department, Hall County and the cities of Flowery Branch and Gainesville. In addition to the public recreation areas, 12 service groups or clubs hold leases on project land for development of recreation facilities for their members. Seven concession marinas provide various services for up to 20,000 power boats and sailboats on a peak-use day. The largest of these marinas, Holiday on Lake Lanier Marina, has accommodations for mooring more than 800 watercrafts, including houseboats, cruisers, sailboats, and runabouts. Holiday's advertisements claim it to be the world's largest inland marina. The fifty-three boat launching

Trailer-weary boats feel the soothing waters of Lake Lanier where 53 launching lanes dip beneath the surface. On peak-use days over 20,000 powerboats and sailboats are on the Lake at the same time.

To get to Lake Lanier the people of Atlanta can row up the Chattahoochee, hop a freight or take to the highways. No record has been kept of how they arrive, but visitation (which is a congressional measurement of reasonable time an individual spends at a site for recreational purposes during a 24-hour period) now exceeds the hundred million mark and quite a few visits are by Atlantans.



Vandals leave a sorry site, and a sign reminds the public of who suffers the cost in dollars and inconvenience. Selected rangers have recently been authorized to issue citations, supplementing other law enforcement arrangements.

Among the regular users of the Lake are those who opt for houseboats. They and others who come for different types of recreation have placed the Lake's annual visitation at about the 14 million level.

lanes constructed by the Corps are heavily utilized by the Lake's boat users. The usage last year, counting both single and multiple uses, amounted to 2.9 million.

Fishing at the Lake is excellent. The resource manager says, "Lake Lanier has a variety of game fish species. Catches of largemouth bass, white bass, crappie, bream, yellow perch, rainbow trout, and catfish are common, with occasional catches of walleyed pike and smallmouth bass." Recreation activities, such as picnicking, camping, water skiing, swimming, and sightseeing are some of the other major activities on the Lake.

Construction of new recreational facilities is continually necessary to accommodate the Lake's ever-increasing uses. We are making plans for the construction of additional picnic and camping facilities in eight public-use areas this summer and fall, if funds are available. Hall County is adding facilities each year to the public-use areas which they lease, and the Lake Lanier Islands Development Authority is in the process of developing its leased land. The latter holds a lease to four islands, one-half mile offshore with a combined area of 1,070 acres and 19 miles of shoreline.

Georgia's Governor, Jimmy Carter, in commenting on these Islands, said, "The State of Georgia is blessed with an abundance of natural resources and scenic attractions, most of which are still far below their potential as sources of recreation and relaxation; and I know of no area of the State with greater potential for this sort of development than the Lake Lanier Islands."

A great deal of detailed study and industrious planning preceded the initiation of construction on the Islands. An economic feasibility study, made five years ago, later evolved into a master plan for the Islands' recreation development. With the need and potential for this development established, the Economic Development Administration (EDA), in 1969, provided $1,403,000 for initiation of construction. The EDA funds were contingent upon Georgia providing funds of an equal amount. The Bureau of Outdoor Recreation also allocated $150,000 on a similar basis. Appropriations by Georgia provided the essential matching funds, and the ground breaking for this unique recreation complex commenced.

The resort development on the Islands will provide dining, lodging and recreation facilities not only for the city of Atlanta, but also for the residents of the southeastern States. Major General William A. Cunningham (Ret.), executive director of the Lake Lanier Islands Development Authority, said, "Atlanta has 1.5 million people; 2.5 million people are within one hour's driving range of the Islands; and it is from those people that we shall be drawing our daytime visitation. For the nighttime visitation, we are counting primarily on the people who can reach here in a day's drive. In that connection, we serve a population in excess of 30 million people." The master plan for the Islands envisions a recreation complex which will satisfy the needs of all visitors utilizing this scenic area.

Sixty-eight recreation sites are kept ready for public use, including 15 under lease to State and local groups. One of the 15 is Holiday on Lake Lanier, a home for about 800 boats.

The concept for the development of the Islands is for the Lake Authority to develop the road network, essential utilities and certain recreation facilities, and then to turn to private entrepreneurs for development of the dining, lodging, shopping and convention facilities.

Development of the Islands commenced when the Corps constructed a $500,000-bridge under special legislation to provide access from the mainland. The bridge leads into a basic road system on the Islands put there by the State of Georgia and Hall County, and the Lake Authority currently has a number of road contracts underway. A complete water distribution system is under construction, including an elevated storage tank. The sewage collection system and sewage treatment plant are being worked on, while the administration and maintenance buildings are nearing completion. Ninety camping sites with underground utilities are complete and will be served by four comfort stations and a campground manager's office and trading post, now all under construction. A 1/2-mile white sand beach pavilion is being finished. The sand of the beach will be placed on a flexible membrane to prevent mixing with Georgia's famed red clay under the beach area.

All sitework is nearing completion for the village shopping area, including the shoreline bulkhead and esplanade. A championship 18-hole golf course should be ready for tee-off by fall, a course with six over-the-water holes. Local utility companies are completing the laying of cables and conduits for electrical power, telephone and gas service. All utilities are being installed underground.

The Lake Authority is currently negotiating with several firms for immediate development and operation of the Village Complex, the Golf Course Inn, Family Vacation Hotel, the enlarged campground and the marine and aquatic activities. A number of qualified investor groups has indicated an interest in the further development of the Islands. General Cunningham reports that a nationwide campaign turned up 20 separate proposals for development of the campgrounds alone. Indian Acres International, a subsidiary of the Chase Continental Corporation, will operate and develop 800 new campsites and will also operate the 90 campsites developed by the Lake Authority. All campsites will have electrical and water hookups and about 50 percent of the sites will have sewerage hookups. A family recreation center will be constructed for use by the campers and will include a game room, teenage activity center and swimming pool. General Cunningham expects to have over 200 campsites ready for use this year.

The Golf Course Inn, with 200 rooms and a lakeside terrace restaurant, will cater to the golfers and also have a good water orientation. This Inn is scheduled to be available to the public by November. The Family Vacation Hotel, with 144 rooms, will be a complete recreational complex with swimming pool, tennis courts, and swimming beach. This hotel, opening this year, will cater to the vacationing families and older people. The Village Complex will consist of facilities for refreshments and also contain service-type stores and specialty shops with initial service stores open this summer. Arrangements have been completed by the Lake Authority for aquatic entertainment in the bay adjacent to the Village Complex. Twenty-one aquatic shows a week will be produced free for public enjoyment, commencing this summer. This entertainment will consist of water skiing demonstrations, wind surfing, and various other aquatic activities. An excursion boat will also ply the waters of the Lake, operating from the Village Complex.

Major developments planned for the future consist of a Resort Lodge-Convention Center and a Family Cabin Area. The 500-room Resort Lodge-Convention Center, according to General Cunningham, "will lend itself to the resort trade in the summer months and association conventions and management-executive seminars in the

winter months." This facility is planned for operation in 1973. The Family Cabin Area, consisting of 150 individual cabins to be available on a rental basis, is also planned for the Islands in the future.

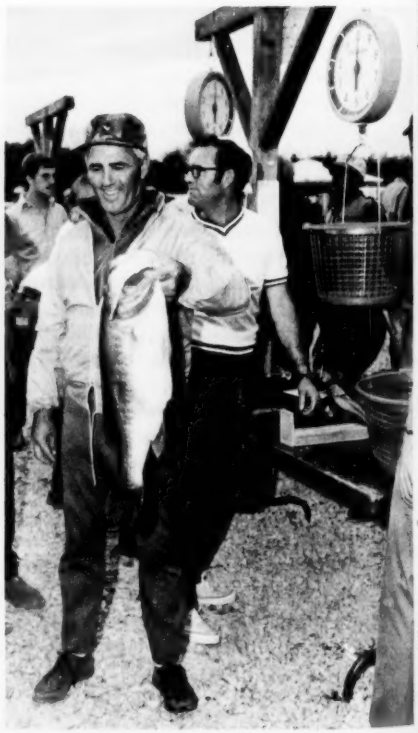
High quality standards have been set by the Lake Authority for all construction on the Islands, insuring a minimum disturbance to the ecology. From the beginning of construction, the goal of the Lake Authority has been to disturb the natural environment as little as possible and to balance the manmade facilities with the natural resources of the Islands. Year-round sustained operation is planned, with a rate of 3 million visitations annually by 1975, when the Islands are expected to be in full operation. By that time, with the Islands fully developed, the Lake Authority is expected to be financially self-sufficient. The development of the Islands will increase the need for additional water-oriented recreation facilities at other parts of the Lake for those visitors who will spend time on the Islands and then fan out to look for other recreational experiences.

Atlanta has been proclaimed by many to be "The Inland Boating Capital of the United States," and Lake Lanier is the major area used by Atlanta's thousands of power boat enthusiasts. Of the thousands of power boats which use the Lake on peak-use days, over 1,000 sailboats on those days will cut through the waves on racing courses while others who are sailing will just enjoy a leisurely afternoon cruise. When asked what elements combine to make the Lake excellent for sailing, K. C. Lattimer, commodore of Lake Lanier Sailing Club, replied, "Just what you see from this pavilion. Lake Lanier is beautiful and big enough to accommodate a lot of water activities. These open areas of water make for good sailing. For long distance races, a course 15 to 25 miles can be set. A second essential element which we have is good winds, almost year around." The Lake Lanier Sailing Club, with a membership of over 200, is a member of the North American Yacht Racing Union, which is the authoritative body for official sailboat racing in North America. The Union is divided into regional groups such as the Dixie Inland Yacht Racing Association with 19 clubs, and the Lake Lanier Sailing Club is one of these.

Sailboat racing on Lake Lanier commences in early March and extends to the end of November. During that time, races are held every weekend, when weather permits, for the various fleets of one-design sailboats in the club. All sailboats in a one-design class are built to exactly the same measurements. Certain races are also conducted by the club where members of the Auxiliary Fleet compete under handicap rules.

The Auxiliary Fleet consists of boats up to 35 feet long with many of them having very comfortable cabins where the crew can get out of inclement weather. In addition to the sailboat races where club members compete with each other, this year the club will host 12 regattas where members of the 19 clubs in the Dixie Inland Yacht Racing Association will compete for regional trophies. An annual Thistle Regatta, the Old Goat, usually has the most entries. Last year that race had 65 boats on the line with the majority coming from other sailing clubs in the south, east, and midwest. In addition to regional competition, the club conducts national championship races. In April, the National Butterfly Single-Handed Championship Race was hosted by the Lake Lanier Sailing Club, and sailors from all over the

Campers seek the best spots at 450 campsites.



This one waited for the Lake Sidney Lanier 1972 Invitational Bass Fishing Tournament to take the bait.

United States competed for national honors in this event. Some of the sailors coming from greater distances brought their own sails and borrowed boats from the local club members.

Management of a water resource project, visited by over 200,000 people on a heavy-use day, is a difficult task. Last year's visitation recorded at the Lake was 13,700,000 recreation days. By comparison, Yellowstone National Park recorded a visitation of 2,126,000. The resource manager is getting ready for greater numbers for at least the next two or three years, because he believes the establishment of the Lake Lanier Islands Development will cause an increase in both summer and winter uses.

The major management problem at the Lake is encroachment and trespass on project lands by the adjoining property owners. The project boundary is located very close to the top of the power pool, the lake level maintained during the recreation season. With the project boundary so close to the Lake shoreline, adjoining property owners are able to build a home or summer cottage on private property just a short distance to the water's edge. Until last summer, the exact project boundary was not identified on the ground for the entire project. The completion of that monumentation of the boundary has revealed hundreds of encroachments. Most of the encroachments are of a minor nature and can be corrected without much difficulty. Some encroachments involve portions of buildings, and these cases are more difficult to correct. For instance, the recent survey revealed that there are nine existing homes which have porches or sundecks located on Federal property. All boundary corners are now monumented, and trees on the Government property line are marked for easy identification of the boundary. Efforts are now being made to negotiate corrections of all encroachments on project land. Since the project boundary is now monumented and marked, an additional maintenance chore has been added.

Lake Lanier has its share of floating facilities, primarily boat docks and boat houses. Over 3,000 permits have been issued for floating structures. Harvie Jorden, assistant resource manager, claims that the primary problem is finding a space to put them. With adjoining property owners located on narrow lots in small coves, the requests for private floating facilities exceed the shoreline space. With limited shoreline space available, it has been necessary to stop issuing permits for floating facilities in various areas, and the need for an evaluation on the use of the entire shoreline is now apparent.

Another management problem is the lack of manpower to service the 3,100 permits and licenses issued at the Lake last year. An inspection must be made by a ranger for each permit or license issued. If the inspection reveals a deficiency in the facility for which the permit or license is issued, a letter must be sent to the individual involved, requesting correction of the deficiency and a later inspection made to determine if the deficiency has been corrected. This workload, together with other management duties, taxes the small staff in the resource manager's office.

Vandalism is another severe problem at the Lake. Defacing signs, writing with spray paint on buildings, destroying picnic tables, stealing traffic counters and destroying water pumps are but a few of the acts committed by vandals. "Vandalism runs in cycles," according to Mr. Patterson. "You will go along two or three weeks and not have any trouble, and all at once, trouble breaks out everywhere." Mr. Patterson and his staff rely on the sheriffs of adjoining counties, State Highway Patrol and the Georgia Game and Fish Department for law enforcement at the project. He points out that cooperation received from all of these groups has been excellent. Nevertheless, some types of vandalism continue, and commencing with this year's recreation season, designated rangers at the Lake have authority to issue citations for violation of those regulations listed in Chapter Three of Title 36 of the Code of Federal Regulations. It is anticipated that such authority for rangers will serve as a deterrent, reducing vandalism.

Lake Sidney Lanier, like the man for whom the Lake was named, touches life at many points. The Lake provides relaxation and recreational opportunities for the millions of visitors who use its public-use areas. The Lake supplies an area where sailors from all parts of the United States may compete for national trophies. The Islands of the Lake furnish natural resources which will be utilized as a backdrop for water spectaculars, championship golf and convention headquarters. The Lake challenges management personnel to preserve and enhance the available resources for the many diverse interests of the recreating public. Lake Sidney Lanier will continue, in the future, to provide the basic ingredients for an expanding recreation program and will endure as Dixieland's Playground.■

Endless Alert:

by Edwin E. Chandler

THE JOB OF A RESIDENT ENGINEER

Where U.S. 59 crosses the Arkansas River just south of Sallisaw, Oklahoma, the scene is one of apparent serenity. For there, below Kerr Dam, fishermen line the bank while others try their luck from boats anchored a few hundred yards downstream; sea gulls float on air currents, sailing in for the catch of fingerlings that venture too near the surface; swimmers on the upstream side bask in the sun on a mile of sand-nourished beach; and freight-laden tows glide in and then out of the lock chamber. Only the churning wake of towboats and water gushing through tainter gates give an outward inkling of the forces in motion within and beyond the structures and along the waterway.

This point on the river is part of the last leg of the $1.2 billion McClellan-Kerr Arkansas River Navigation System, the largest single project ever completed by the Army Corps of Engineers. The Oklahoma section, which covers 140 navigation miles between

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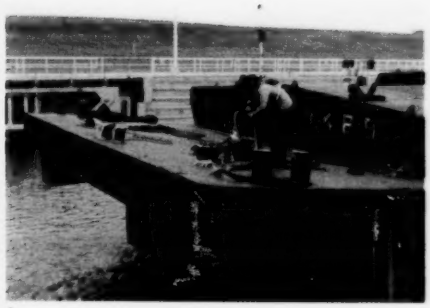

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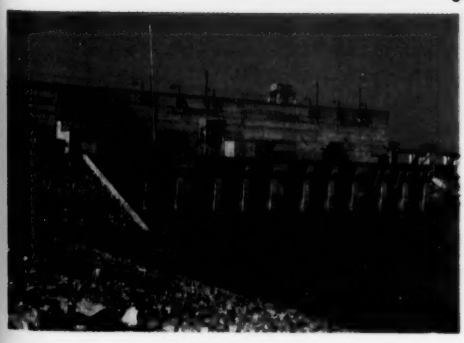


1
Trees. A few pine trees at locations set aside for wildlife and other areas will be planted. The resident engineer, left, and a representative of the Oklahoma Department of Fish and Wildlife open the first bag of trees for a wildlife area near Kerr Dam.

2
Barges. When loaded, some need a 9-foot cleared channel for passage.

3
Planes. For a bird's-eye view of river conditions planes are the answer, and when needed they can bring in Division expertise, as this one did, on short notice.

4
Patrols. The Highway Patrol and Lake Patrol operate as a single organization in Oklahoma, simplifiying search and rescue and other missions requiring coordinated action on land and water.

5
Dams. They form the navigation pools and some have power generation units. They thrive on good maintenance or depreciate rapidly without it.

...nes. Without them, operation would come to a ...t. Bulkheads and debris baskets and shafts ... pieces weighing many tons must be moved ...ularly as part of the maintenance program ...locks and dams.

Fort Smith, Arkansas and Tulsa, has five sets of locks and dams with two of them for power generation. The pools and channel have a total of 60,000 acres of water surface, and the system also includes 55,000 acres of land. To operate and maintain the system requires a work force of 130 people, not counting those on contract jobs, and a $5 million annual budget. Besides payroll the major budget items are for dredging, bank stabilization, operation of a work fleet, transportation, powerhouse and lock maintenance, roads, recreation facilities, new buildings, supplies and equipment.

Headquarters for operation and maintenance of the system is a Project Office near the Robert S. Kerr Dam about 9 miles from Sallisaw. Visitors who stop there must work their way through the traffic of work boats on trailers, road graders, trucks and other vehicles loaded with equipment, supplies and work crews. Visitors can take refuge within the building, but some of the sound follows; and added to that is the muffled clanging from a repair shop at the rear, the incessant static and chatter from open radio receivers, typewriters and telephones and buzzers and a din of intense discussion from rooms along the corridor. There, when he isn't boating or riding or flying over his domain of water and land, is where they can find the man in charge of waterway operations, Resident Engineer Curtis E. Weddle, Jr.

If the callers stay around awhile, they will have a chance to observe how a former assistant professor dovetails the theories of academia into a highly demanding operation and maintenance program. Their immediate impression might be amazement at his calm and deliberate handling of problems coming from all directions. However, if they knew his family, they could surmise that he encounters the unexpected with the sage understanding of a man whose daughter is passing through the pet white rat era. They would know that he likes his work territory enough to return for camping trips with his son's scout troop. They might also detect that, to him, happiness is having a 4-year-old and a house on 50 acres and living in Oklahoma and working on the waterway.

For our readers, *Water Spectrum* asked Curt Weddle to tell about the waterway from his vantage point and to discuss what it is that a resident engineer does. Among the points brought out in the discussion were these:

WATER SPECTRUM: As jobs go, Curt, would you consider yours ideal?

RESIDENT ENGINEER: Some people might not think so, especially at times like last Friday. Sand and rock piled up under a lock gate, and we had to work all night to get it back in operation; and before it was over we all got soaked. But I like it. It's the kind of job I've wanted for a long time.

Did you have to work under water?

No. I asked for a diving team to come over from the Little Rock District the next day, and they checked out the work to see if everything was in order.

Do you ever do any diving?

Haven't for a long time. I did go to refresher session though in Florida a few months ago, so that I can have a better idea of what to expect from diving teams and what kind of safety and other support they need to do their work.

You are listed as having taught at Missouri's School of Mines at Rolla; but what was your job before coming here?

At the time I asked for an assignment at this place, I was chief of the reservoir branch in the Tulsa District Office. Before that, I was a resident engineer here in Oklahoma at Lake Eufaula. But we didn't have anything there like the McClellan-Kerr Arkansas River Navigation System to contend with.

You seem to be at the interface between the physical resources of the waterway area and the community of actual and potential users. What are you doing to inform people about those things they want to know, need to know or have the right to know?

I'm not fully satisfied with what I've been able to get done on that score, but I'm working at it. I accept several invitations a month to discuss points which different groups are interested in. Tonight I'll be talking to the Coast Guard Auxiliary, and tomorrow I've been invited to go to a high school. A couple of weeks from now, I'll be at a chamber of commerce meeting. I write a weekly column for about 10 newspapers in the area and I furnish information for use of the public affairs officer in the District Office at Tulsa.

What kind of items do you cover in your column and what response have you had?

So far I'm rather pleased with the response. Every column has stimulated some type of feedback and some type of discussion that people tell me about, and that's one of the main reasons for writing it. I tell about problems we are having and what we are doing about them. I give weekly accounts of tows that go through and what products the barges have on them. Things like that.

Curt, your inventory and staff listings show that you have about 130 people working here in the area, not counting those on contract jobs, and that you have 18 radio transmitting and receiving sets. The office here is monitoring navigation and other frequencies and you have direct phone lines and regular phone service. Communication is going on constantly and every conversation seems to require some type of action. What are some of the calls you have handled in the last two hours?

Talked with the District Office in Tulsa about a few problems that have cropped up. We're only in our second year of operation, and in a system of this size it takes a few years to get through the shakedown period. Take the water leakage in the control room at the powerhouse, for example. We have decided to use an experimental joint treatment to stop it; and the Colonel said get on with it. So I told Tulsa we'd attend to it. We have some loose bricks at the lockhouse here at 15, and we discussed the use of either silicone or an epoxy treatment to keep it tight. It's a weathering cycle. Mr. Bond, the powerhouse superintendent, called to say that Division people from Dallas will be here Thursday to look into our contention that water discharges for power generation are aggravating our dredging problem.

In what way?

It's a matter of suspended particles. If we are, say, discharging 35,000 cubic feet of water per second (cfs) with three generating units and they are cut off at the same time, we go from 35,000 cfs to nothing. The stream velocity slows down and the suspended particles drop out into the navigation channel and then we have to dredge it out of the channels.

What can you do to keep that from happening?

Power people don't want restrictions placed on generation, but we would rather not go offline nor online with units in too rapid a sequence. We want hour spacing, dropping down from four, three, two, one, zero and this is only during a critical discharge time when we have what we call fluid motion on the bottom of the channels. So I've got to get that point cranked in.

Is the problem, then, more one of rapid cutoffs rather than going online too quickly?

We have one problem from discharging. We are going into a dredging sequence in the stilling basin below 14 and when the discharge is over 8,000 cfs the dredge can't hold its position and when we can't dredge we have to pay 80 percent of the dredging costs for standby time. That would run into a pile of money so we've got to get that straightened out.

Any other problems at the powerhouse?

Mr. Bond reported trouble under unit four. Rocks. About two yards of rocks. Don't know where they came from. Probably left there by contractor operations. But they are causing unwatering problems and we've got to figure out a way to get them out. Mr. Bond has to go to Weber Falls to check on construction of a powerhouse there. Really none of our business, except one of these days we will have to operate it and we want to know what we are inheriting. He has to be here tomorrow because about 20 people are coming from various powerhouses to see what we are doing to fix our circuit breaker trouble since they have had circuit breaker trouble too.

What are some of the other things you must attend to today?

I've got a reservoir manager named Sturdy, who has a master's degree in wildlife management, and the District Office wants to borrow him to work on some environmental impact statements. So I've got to schedule him for 60 days there beginning Friday.

What environmental impact statements will he be working on?

On operations and maintenance. We have to make environmental impact statements on our activities and we are in the process of doing that. Speaking of environmental matters, we've got to start a new maintenance and storage building that blends in with the environment so that it's unobtrusive but still functional. If you wandered through this building you could see how we've got it cut up for offices. It was supposed to be an area for vehicle and equipment maintenance; but we've got so many dang functions and people that must have office space that we don't have enough room for maintenance work. The new building amounts to about $40,000 of my total budget, and I've got to get it moving.

Any particular navigation matters coming up today?

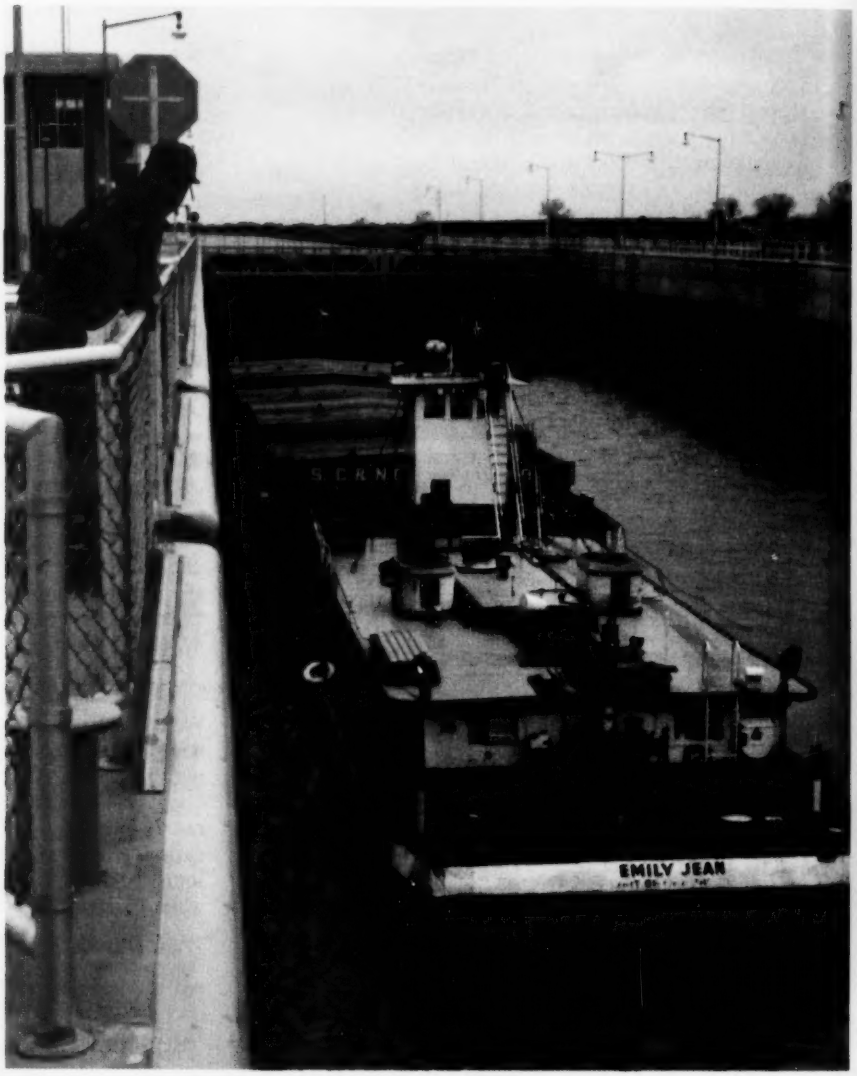
We've got to update a navigation notice advising navigation interests of the situation of the system between Garrison Avenue at Fort Smith and the Port of Catoosa. The notice mainly involves the removal of restrictions we had placed on them. Another thing I have to do is get the district to modify a contract to replace some rock that washed out. The rock is needed to deflect water in the vicinity of Lock 14.

What District Office branches do you usually work with?

All of them. Navigation, engineering, safety, reservoir, operations, and other branches.

A lot of risk capital has gone into the waterway, and on the basis of the way things are going during the initial stages, do you think the nation will get its money's worth out of it?

I'd have to rely on the long-range projections that the Congress based its appropriations on. According to the projections, the eventual benefits will run about $1.50 for every $1 of cost. Some think benefits will be higher than that, but in any case, I think the risk of investing in the waterway should be considered in terms of what risks we would have faced had we not built it. I think the waterway has to be considered as a hedge against economic stagnation, and a hedge against disasters from floods, and a hedge against losses at other times during water shortages. Some considerations can't be completely quantified in the form of dollar returns.



Tows. This one had dropped five barges at a port downstream, with the loner going on to Catoosa. Locks can take six at a time, two abreast.

Marine Facility. This one, with the Corps' half in the background, is shared with the Coast Guard. The home base of the Corps' work fleet for the Oklahoma section is here near Sallisaw.

Repairs. Every piece of equipment, sooner or later, must have them. And all equipment must be serviced. Maintenance records are punched into computer cards at Tulsa, and periodic print-outs help flag times that various equipment need servicing.

Maintenance. Coordinated muscle power fills in where hoists can't reach. The Resident Engineer is on constant lookout for design modifications which will make maintenance easier and less expensive.

Lockmasters. All came with experience gained on the Ohio, Missouri and other rivers. They communicate with the tows by radio, buzzers, bells and horns.

Curt, the projections on estimated annual benefits from the operations as a whole go up to $75 million a year. The projections also show that that level of benefits will be reached in 10 years. What is the progress on these projections?

Well, let's look at the eight activities that make up the projections. Transportation is the main one and it's based on an eventual 13 million tons of shipping per year. We are into our second year and the amount is already over 4 million tons. That's nearly twice as much tonnage as the amount projected for this stage of development. However, transportation makes up only a little more than half of the projected benefits; and the seven other activities consist of power generation, flood control, channel stabilization, water supply, fish and wildlife, recreation and redevelopment. Power, of course, is already being generated; flood control is based on hydrologic cycles, and we have gone through a minor flooding cycle without severe damage. As for channel stabilization, we have kept the water in the channels. We are maintaining an adequate water supply and benefits are already being derived from that. Fish are thriving in the waterway and areas have been set aside for wildlife. Recreation benefits can be estimated on the basis of visitations, which reached 300,000 for Kerr Lake alone during the past year. Redevelopment benefits are coming in the form of new businesses and industries along the waterway. Of the eight areas on which annual benefits have been projected, transportation represents about $40 million and the other seven about $35 million. Power generation is the largest of the other seven, valued at nearly $15 million per year, and water supply benefits have been projected at a little over $800,000 per year. There is no question about it. Benefits are being realized at the rate projected for this development stage and there is every indication that, within 10 years if not before, the level of benefits will reach the $75 million annually.

What about new commercial and industrial starts? How can you determine what influence the new waterway has on business and industrial expansion?

Every time an industry announces plans for expansion, the industry is specifically asked whether the expansion is because of the river. Also, the industries are polled on other reasons for locating in the vicinity of the waterway. When the replies are analyzed, the major reasons can be easily identified.

What is the estimated value of new starts in Oklahoma?

New starts in Oklahoma that can be attributed to the waterway amount to around $300 million. These include mining, industrial parks, a uranium plant and plants for rubber products, steel products, chemicals and electric power generation.

Some of the biggest investments that have been reported are for nuclear power generation. How do you associate that type of investment with the waterway?

These power plants are coming in to generate electricity for new industries that are locating along the waterway and for the anticipated increase in population density that accompanies business and industrial growth. Because why did these investor-owned firms put up that kind of money if their analysis didn't show there would be people around to use the power?

What about people who already live in the vicinity of the river? Is the waterway affecting them?

Economic growth affects them, but the most noticeable thing is their visits for some form of recreation. That includes sightseeing to watch tows lock through and for longer visits for camping or picnicking or swimming or fishing or walking through nature trails or boating or engaging in some other recreational activity. A lot of people are coming out to public-use areas and project sites along the Oklahoma section; and we are getting things ready to accommodate much greater numbers.

At some places across the country the users leave restrooms and other facilities appearing like they were picked up at a slum clearance; how do you handle that?

Fortunately, we don't have that problem. Most of our visitors are Oklahomans.

Touche'.

Just kidding. We get good groups of visitors from all over and we try to keep things as nice as we can for them. I've found that as a rule if people find facilities neat when they arrive, they tend to leave them neat when they depart. Nevertheless, we follow a hard-and-fast rule that seems to work. We contract the cleaning operation; but before we accept bids, we take the prospective bidder to the public-use sites and make sure he understands what performance is required, how many feet from a picnic table must be policed, how any markings on walls must be removed, and how any soiled tables must be scrubbed down. We cover every point in his work. That way we have had a good understanding of what is expected and we've been pleased with the result.

Then you haven't had any vandalism troubles.

Not exactly. Unless you would put the two boys who started up the bulldozer in that category.

Yes?

I don't like to think about it.

When you do, what do you recall?

Well, a contractor went off and left the key in the bulldozer and these two boys came along and they apparently couldn't resist seeing what it would be like to operate one and somehow they got it started and in gear and going and they ran it over and through about everything at the construction site before they could stop it or be stopped. I don't like to think about it.

We won't dwell on it then. But what has been the greatest crisis, Curt, that you have faced since you became resident engineer?

We've had problems like the break in a 16-inch oil pipeline, but the one thing that reached a level that might be termed as a crisis was getting caught up in an all-out push to put a tow into Catoosa by a set deadline. This was a date that was arbitrarily set as a goal to shoot for. But all the contracts were let on the basis that the deadline would be met and we found ourselves going day and night in a dead run just to meet it. The goal was to get the tow through by the end of 1970; and on the last day, the 31st of December, we took our work barge, waited until a contractor blew out a couple of old tiers of a bridge that was being removed and pushed the barge through, scraping and squeezing between some of the still standing sections of tiers as we went.

Must have been a relief to get past that stage.

In some ways, yes. We made the deadline. But we had to do a lot of refining to make the system ready for commercial navigation and to correct things that were overlooked in the rush.

Like what?

Oh, a bearing for the gear assembly that swings the lock miter gates. That's one of the things. Together, each vertical shaft and gear weighs several tons, and, without a bearing to hold it in place, the whole thing will begin to vibrate and jump out.

What happened?

One did. Final outcome was that we had to move cranes into every lock and install the keepers on the bearings. A simple thing to fit into place once we got the 3-ton gear and arm and the 3-ton shaft lifted out of the way.

You mentioned a 16-inch oil pipeline problem. What was it?

It was a 16-inch line that broke under the river. It broke on a Thursday, just as we were having a heavy rain and a heavy runoff. So when we got the rise in the pool, the oil came with it. And man, was it crud about yea thick. We had to back track up the river trying to find the source. We first thought it came from an uncapped hole in a lake bed where we have had to plug some that owners left uncapped. By law, the owner of an abandoned hole is supposed to cap it, but you can't always find the owners after they move out.

Did you check the lake bed?

I sent rangers out to check that place and at the same time I had rangers leap-frogging up river until we finally found that the oil was coming down the Verdigris by the Port of Catoosa. My area stops at Catoosa, so I called Oologah and Hulah to ask them to send rangers down river to see if they could locate any leaking oil wells. We traced it down to a 10-mile stretch on the Caney River between two highways. But dark closed in, and we couldn't pin it down until the next morning. That was when we found that it wasn't a well after all, but a break in a commercial pipeline.

Didn't the pipeline company know that their flow volume had dropped?

I talked to the vice president of the pipeline company that morning and they knew they were losing oil, but didn't know it was in a river. They cut off valves at stations on each side of the break, but we were getting all the drainage. Weather was clear enough for a plane by then and they had one pick me up at Sallisaw and I went over the area but there were no roads leading to their line in that section. The pipeline company finally pushed through with bulldozers and shut off valves nearer the river before all the oil drained out, but in the meantime we were accumulating all the oil at Number 18 and Number 17.

Were you able to catch it?

That just wasn't our day. We were getting water at 23,000 cubic feet per second coming through. That's not much but it is for the Verdigris. I hoped to bottle up the oil at Number 17 where we have a little dam. We have about five miles of river there before it gets back into the navigation channel. But I couldn't catch it. The runoff from the rain was still too heavy. All I could do at 17 was keep it out of the locks. That was easy. We just shut off everything and let it run through the dam. But when the oil got to Weber Falls, we couldn't do anything with it. What didn't cling to the structures, washed on down the river.

How did you clean up the locks?

We sprayed with an emulsion and then knocked it off with a water blaster. The pipeline company had agreed to pay for the clean up, so we tabulated the cost and sent them the bill.

Is that sort of thing likely to occur again?

I hope not; but if it does, we would know what to expect and be better equipped to handle it.

What capability do you have for responding to emergencies?

In the first place, we have a man on duty 24 hours a day seven days a week at each lock. Once he gets the message that an emergency of some kind exists, he can relay it by radio or phone to a ranger, or someone else, who can help solve the problem. Here in Oklahoma the Highway Patrol and Lake Patrol have been combined into a single organization, the only State to have that as far as I know, and this simplifies matters if the emergency shifts from the water to land or vice versa. The Sheriff's Office in each county and the Coast Guard are always ready to help when they can, and in some cases private and commercial crafts with radios can assist.

Survey Boats. Trouble shooters ply the waterway, study problem conditions and recommend solutions. This one is going in from a day downstream from Kerr.

How long has it been since some type of emergency has come up on the waterway?

Last night. Two. The Emily Jean with a tow going downstream came across a boat in distress. They picked up three adults and a 2-year-old. They put a line on the boat, but it sank. They put the occupants ashore at a highway bridge. Later, the Margie Taylor reported a capsized boat floating down the channel bottom side up. A ranger will bring in the boat if no one else does. We haven't heard anything more about the people that got off at the highway.

You mentioned two. What was the other?

After I got home last night, the Coast Guard called to say a woman reported that her husband, with a known heart condition, hadn't returned from fishing and she had expected him back before dark. He had gone somewhere along the waterway, but she didn't know where. Well, we have several hundred miles of shoreline, but we knew where the fish were running heaviest and we figured he would be there. So one of our people in that area went out to see if they could find his pickup truck. At the same time other areas were being covered by the Lake Patrol, which has the primary responsibility for search and rescue missions. Tornado warnings were out and he could have been in real trouble. The search had been going on for about two hours and a half before we called it off.

Dredges. When water velocity drops, the suspended particles settle to the bottom — infringing on the depth of the 9-foot channel. Shifting currents transport sand and debris, interfering with navigation. Thus dredges have a ceaseless chore.

To wait for daylight?

No. The man's wife called and said he had just walked in the door.

Do you have any kind of storm warning system?

The Weather Bureau takes the lead in that, but we are working out a system now to supplement what they do. We make use of the radio and plan to revive the Weather Bureau's flag warning system as well because a lot of pleasure boats don't have radios. We also need some wind gauges on the river, because the readings of gauges located several miles from the river may not be giving us the information we need. When a tow is approaching or leaving a lock, we would like to be able to tell him the exact direction and wind speed he will encounter at that lock.

Do you have a system for keeping barge traffic aware of changes in river conditions?

Oh yes! Every day we put out a broadcast on what can be expected during the next 24-hour period. We collect the information by phone from the Weather Bureau and the Southwest Power Administration and then we add points concerning local conditions. Tow operators, and others, can tune in on this report and find out what to anticipate on inflows from power generation and rain, and such things as where to watch for a survey crew or a dredging operation. This is broadcast on the hour from five to eight with each lock operator picking it up, recording it and relaying it upstream. At eight o'clock, the lock on each end of our section puts it out, because their channel 14 band, the one they use, doesn't overlap. If any vessel operator misses the forecast, he can call in and the tape is run for him. It usually takes about four minutes for the report.

In one of your columns, you mentioned that less than half of the 13 firms with Federal Trade Commission permits to navigate the Arkansas are using them, Why not?

My guess is that some are waiting for industrial development to reach a higher level and to see if all the bugs are really out of the system.

Anything in particular?

For one thing, justified or not, tow operators complain about what they feel is the lack of wholehearted cooperation of the railroads along the system.

Lack of cooperation in what way?

Quite often the barges are scheduled to transfer cargo to or from rail sidings and box cars are not always in place and the tow has to wait until cars come in. Added to that is the matter of railway draw bridges. The tows must arrange passage through about six of these on their way both up and down stream. At some of the bridges the tow operators feel they have to engage in a waiting game. Some of the tow people think there is a lot of unscheduled rail traffic just to give them a hard time. We only hear the worst side and not very much about the times when things are going smooth. I suspect the overall cooperation is good, and if a problem does exist at some locality, it isn't one that can't be resolved. I think that all the barge lines having permits will take advantage of their options to operate. When the available freight volume is high enough, the barges will be there to move it.

Freight volume aside, you've mentioned that most of the expected benefits in other categories are being realized. Isn't that enough at this stage?

I don't discount the value of the other benefits. Not for a second. Water for power and for wildlife and fish, recreation, domestic purposes, and the other benefits, are all important. But the basic justification for the waterway is navigation; and even though the 4 million tons is higher than we had expected at this point, I'd still like to see the use rate stepped up. We have the system ready for it.

Keeping the system ready for commercial and public use is the resident engineer's basic responsibility; and in carrying it out he relies on the cooperation and participation of local, State and Federal agencies, business firms, clubs, organizations and individuals.

These activities, for the most part, seem to be made up of conditions that require urgent action, and the forces in motion have a compelling effect on those who are carrying out their assigned missions. This holds true in every arena of activity. Those nurturing the growth of vegetative cover are impatient to complete the plantings which will protect wildlife against predators and the searing sun of summer and the harsh cold of winter. The aesthetic forces that pull people to the area's shores and lakes place pressing demands on all accommodations as well as on those who cater to visitor needs. The economic impetus for industrial expansion and the literal thrust of goods into the navigation channel place heavy demands on the system. The feeding of hydroelectric power into southwestern networks of transmission cables commands total readiness by those who make the energy conversion.

The force of greatest concern, however, is the pooled water itself. Water which is directed through the powerhouse can turn blades that put four 27,000-kilowatt generators online at one time; and water which flows in the navigation channel and through the locks can lift and lower tows weighing hundreds of tons.

These are some of the forces and activities which demand the resident engineer's attention along the entire length of the waterway. And even though a sense of serenity may engulf those who tarry at some places, elsewhere they would find the swirl of matters which require the resident engineer to stay on endless alert—especially now, during the system's early growth years. ■

CRREL

hothouse for cold problems

by Seymour Reitman

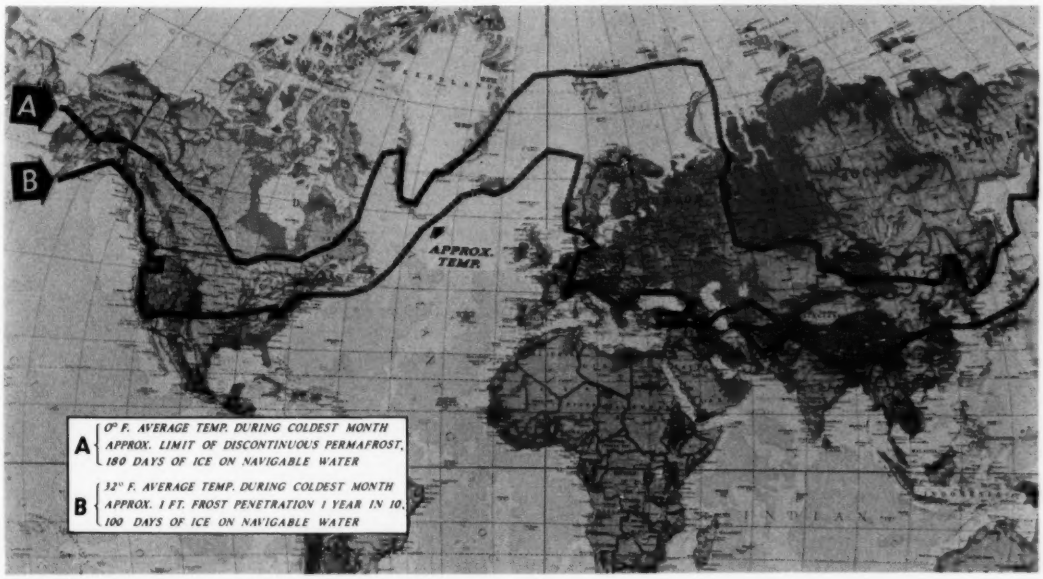
Across the road from a New England ski trail, on land leased from Dartmouth College at Hanover, New Hampshire, stands a two-story brick structure housing a Corps of Engineers organization unique in its dedication to one goal — unlocking the door to nature's oldest and coldest mysteries.

For many years the U.S. Army Cold Regions Research and Engineering Laboratory (better known by the acronym USA CRREL) and its predecessor agencies quietly pursued this goal while its more military organizational cousins were preoccupied with combat activities in the world's "hot" spots. But the recent shift of world attention toward one of the "cold" spots has increased the Arctic's importance and brought about a sudden association of CRREL studies with headline-making events. Such are the environmental and economic consequences of these events that they transcend individual regions or countries in their future import.

As the pressures of population expansion and advances in technology encroach upon a previously untapped, frozen warehouse of some of the world's most precious natural resources, CRREL scientists are being sought after to shed the heat of expert knowledge upon a world of permanently frozen ground.

Thus, CRREL has been asked by the Department of the Interior to provide technical advice on such pressing manmade problems as reducing the potential risks in constructing a hot oil pipeline across 800 miles of Alaska, much of it permanently frozen ground.

Past experience with Alaskan road and housing construction repeatedly demonstrated to CRREL engineers that excavating in permanently frozen ground faces the risk of slicing through huge frozen slabs of ice and soil known as permafrost. Its stability as a structural foundation depends on man's ability to maintain the un-


A
B
APPROX. TEMP.
A
0° F. AVERAGE TEMP. DURING COLDEST MONTH
APPROX. LIMIT OF DISCONTINUOUS PERMAFROST,
180 DAYS OF ICE ON NAVIGABLE WATER
B
32° F. AVERAGE TEMP. DURING COLDEST MONTH
APPROX. 1 FT. FROST PENETRATION 1 YEAR IN 10.
100 DAYS OF ICE ON NAVIGABLE WATER

The cold regions of the world include nearly half the land mass of both the Northern and Southern Hemispheres.

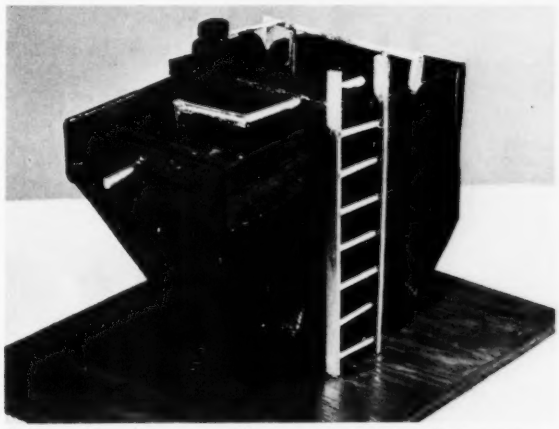
derlying permafrost at below freezing temperatures. A task easier said than done.

Years of observation proved to CRREL staff members that stripping away surface insulating materials exposes this permafrost to higher air temperatures that cause the surface to thaw downward through this moisture-laden substrata. Since the volume of ice in the ground often exceeds that of the soil, the surface seasonally subsides into washouts, gullies or "creeping" slopes in an almost irreversible cycle of thermally induced erosion.

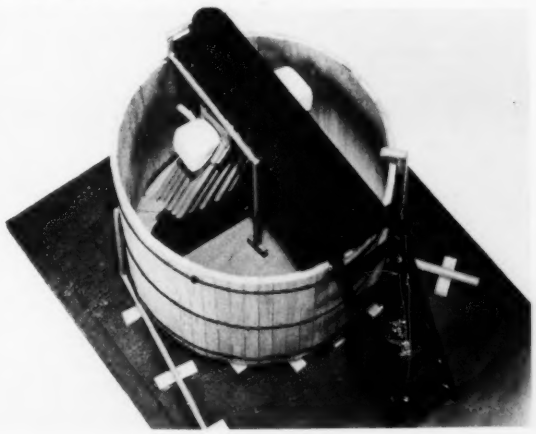
William Quinn, chief of the Northern Engineering Research Branch, mentioned one instance of how such erosion was stopped. He described the inventive technique employed by engineers in covering over a massive ice lens exposed on a slope by earth moving machinery cutting a road north to the Yukon River from the Livengood area of central Alaska.

First they removed the adjacent trees and brush, whose weight might cause the surface vegetation mat to topple over the newly cut embankment. Then they successfully closed the gaping ice wound by encouraging the still intact mat of peat and moss to progressively drape down over the continuously melting permafrost lens. Thus, the natural forces of ice thawing and ground subsidence were overcome to meet an excavation problem with minimal guidance from CRREL, whose North Smith monitored and photographed the entire operation over a period of two years.

Several such ideas grew out of 10 years observation of a test plot near Fairbanks, Alaska. This land had been

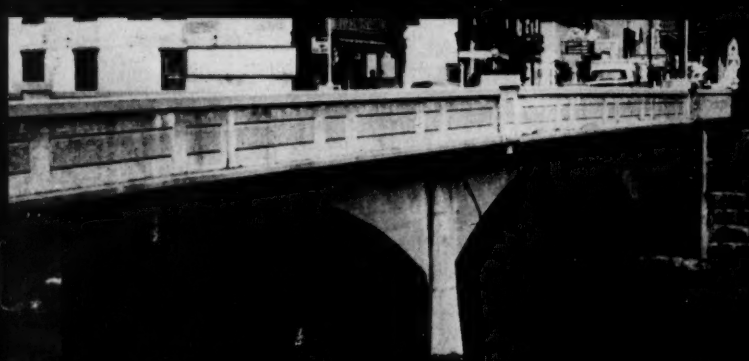


Both models of these portable sewage treatment plants were made by a sanitary engineer to illustrate his innovation. The standard double tank above has been converted into a lighter, more compact single tank below by using a newly patented floating clarifier in place of the second tank.



This photo was taken in June 1970 shortly after road building operations exposed this giant ice wedge on a new road being cut north from Livingood, Alaska to the Yukon River. Beyond the 12 feet exposed to view the ice extends to an unknown depth below the mantle of thawed silts and sands being formed by surface deterioration as the underlying ice wedge continues to thaw. Soil particles embedded in the ice give it a dirty greyish cast.

Winter ice piles almost as high as the of the Main Street bridge crossing the Israel River at Lancaster, N.H., just before the 1968 spring thaw brought severe flooding conditions to this community as pent up river water sou to escape downstream. How often the bridge could withstand such massive pressures before collapsing is unknow and another reason why CRREL is participating in the study of ice on inland waterways. A companion phot shows the normal river level.



A look at the Mississippi River, north of Sartell, Minn., shows typical March icing conditions facing anyone attempting to navigate the river in winter.

An amidship shot by a CRREL scientist shows the extent of pressure ridge activity in the arctic type sea ice surrounding the S.S. Manhattan during one of its historic voyages in search of a Northwest Passage.

Typical ridge height may go as high as 30 feet.

cleared by CRREL to study the depth of thaw into the underground permafrost layer by creating varying degrees of disturbance to the organic trees, shrubs, mosses and peat at the surface. Associated studies of other ground surfaces that had been denuded and darkened by forest fires reinforced these research results. Related work led to CRREL engineers advising the U.S. Air Force to paint runways white in the Arctic to reduce the ground subsidence previously experienced with the use of black asphalt surfaces.

As Fred Crory, Foundations and Materials Research Branch chief, observed about northern construction: "Years of on-site testing have taught us that we have to preserve the stability of permafrost subsoils. Sometimes this can be done by artificially refrigerating or 'freezing back' building and roadbed foundations, a heritage of our many years spent solving military construction problems."

The related biological implications of man's intrusion into this little known area of the world are being investigated under the guidance of CRREL's Dr. Jerry Brown, currently serving as director of the U.S. Tundra Biome Program. This is one of the biome study areas incorporated into the five-year International Biological Program running through 1974. Through the Tundra Biome Center at the University of Alaska, Dr. Brown directs the research activities of personnel gathered from 33 institutions and agencies.

Intended to mesh with studies of other biomes, the tundra biome is being approached as an ecosystem in which the tundra is considered an integrated and dynamic complex of living and dead organic components. Being at the extreme cold end of the climatic range, the tundra possesses unique features generated by its combination of low temperatures and short growing season. Thus, its biotic diversity is low, its vegetation structurally simple and its life forms very tenuous, as shown by the large population fluctuations of many species.

Its capability for regenerating vegetation is so limited that evidence of forest fires and vehicle tracks remain visible long after the event and often begin an irreversible process of tundra erosion.

The lasting effects of any oil spill also become extremely important and CRREL scientists are participating in the search for biological answers to this potential problem.

Although the tundra biome is unique to cold regions, much of the frozen knowledge CRREL scientists accumulate can be thawed out and applied to more temperate climates. Thus, the techniques devised to preserve the stability of tundra permafrost can also be used to artificially freeze other soils to help in excavation, foundations, tunneling, soil stabilization, or underground storage of cryogenic liquids.

A good example is the possible application of Arctic waste disposal solutions to the many tiny American communities farther south that cannot afford the luxury of complicated plumbing. Although research in this area was originally intended to assist remote military stations in Alaska, isolated smaller civilian communities may also reap future rewards.

CRREL is particularly proud of the advances made by one of its sanitary engineers, Sherwood C. Reed, in developing a relatively simple to build, install and operate prototype for a portable system that can process wastewater at its source. Reed replaced the preliminary sedimentation tank of a traditional double tank system with a liquid clarifier floating in the fluid inside the aeration tank.

Aerating this fluid forces it through the floating cluster of 44 circular plastic tubes all glued together that constitutes Reed's innovation. Since each tube is cut at a 60° angle, the solid particles in the fluid settle from the crown to the invert (inside low point) through gravity, making each tube self-cleaning as well. After settling out of the floating clarifier the sludge returns to the bottom of the tank for continual aeration and settling cycles.

Very little excess sludge remains for disposal after a 24-hour period, permitting an operator with minimal training to process 1,000 to 10,000 gallons of domestic sewage daily. Reed says, "My research was deliberately aimed at looking for a system that would provide satisfactory treatment but not require expert staffing or full time attention."

The unique floating clarifier, for which a patent has been awarded, and the use of wood staves substituted for metal or plastic tank walls reduce the need for additional thermal protection in arctic climates.

The long periods of aeration keep the fluid unfrozen, creating an internal liquid thermal barrier for the sewage system components. Up until now, Reed points out, engineers thought they had to create a Temperate Zone climate around a sewage treatment plant due to the heat required to maintain biological activity in the sewage. This requirement adds to the cost. "Besides," he observed, "we've found we could cool the operation down to 33°F and still achieve desirable secondary treatment."

The current prototype has been installed behind CRREL headquarters at Hanover, subject to New England winters, which are less severe than those normally experienced in the Arctic. Therefore, larger models are being designed for testing at a CRREL field facility outside Fairbanks. For reality, the current prototype is hooked into the Hanover city sewerage system and has been quite successful in its New England environment.

The most daring thrust into the research of wastewater management was a recently completed report which represents a total assessment of the current state-of-the-art by a multidisciplinary CRREL research team. Its conclusion that wastewater may also be treated by

spreading it over the land has led to another innovation — planned construction of an experimental *land disposal* treatment facility. CRREL will test this potential by applying previously treated wastewater directly to the soil through spray irrigation onto concrete lined test plots. The wastewater will be allowed to percolate through the 6-foot deep ground plots, which act as "living filters," before being returned to a sewerage system for disposal.

This recent interest in wastewater treatment indicates CRREL's changing scope. From predominantly military construction projects in earlier years, CRREL personnel are becoming more involved in the application of their expertise to civil works planning, construction and operations in the Arctic and subarctic.

Another project that illustrates CRREL's participation on behalf of the Corps of Engineers is a 3-year "Winter Navigation Program" authorized by the River and Harbor Act of 1970. Begun in 1971, this program is designed to explore the feasibility of extending the navigation season on the Great Lakes-St. Lawrence Seaway system.

Responsible for the ice engineering phase of this program, CRREL is working with personnel from other Federal agencies under the direction of a multi-agency organization.

CRREL's specific duties include the study of ice problems that prevent vessels from traversing this seaway during winter months. The basic difficulty in extending the navigation season into midwinter is the progressive thickening of the ice through the winter months. Thus, a vessel attempting winter passage can anticipate new problems in the absence of spring thaws that help weaken the ice cover several months later. As Al Wuori, Applied Research Branch chief, describes it: "We're seeking to predict and analyze these anticipated problems. For instance, we're trying to establish a stable ice cover for parts of the St. Lawrence River. We hope to show that it's possible to construct ice booms along both sides of the navigation channel to prevent loose ice floating downstream from forming an ice jam."

This year's plan includes preparations for measurement of the ice force applied to one of the existing ice boom cables at its shoreline anchor point. Meanwhile, an instrumentation package is also being developed in CRREL's laboratory for use next winter to measure ice forces at the central part of the boom itself.

The goal is to develop criteria that can be applied to an optimum design for anchoring the ice cover along a navigation channel that would be kept open in future winters.

An approach to a particularly vexing portion of the system, the Lime Island bend of the St. Mary's River, has been to test install a 3,000-foot air bubbler system along that part of the navigation channel.

The intent is to attack the ice cover from underneath by pushing the deep, warmer layers of water toward the colder surface along with air generated turbulence. If the warmer water keeps melting the bottom of the ice cover it should stay thin enough to crack under the force of moving vessels throughout the winter. A similar air bubbler concept has been applied to the gates of each lock in the seaway to keep them free of floating ice.

Before man's attempts at extending the navigation season, the heavy winter ice packs that formed in the seaway were undisturbed by manmade forces. Now their potential strengths will have to be tested for possible damage to shoreline structures. Passing vessels may shove this heavier ice sideways into these structures under midwinter conditions. So his group, Wuori says, will try to imitate these potential forces through model simulation as well as performing field measurements of these forces.

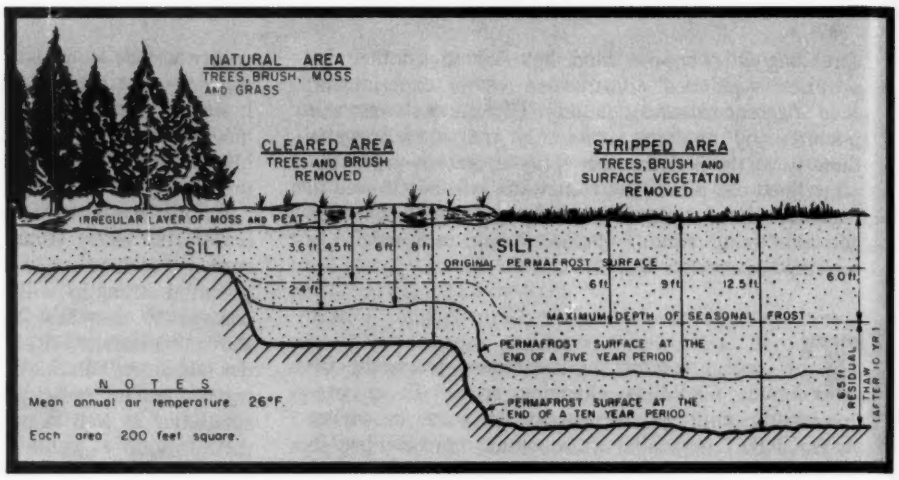
CRREL scientists are also resorting to what might be called "towboat tactics" in attacking the upper Mississippi's winter navigation problems. A CRREL team boarded the Renee G this winter with instruments to measure a commercial towboat's ability to push barges up and downstream between the Quad Cities and the Illinois River. With the aid of this data, CRREL team members expect to predict the vessel power required to break any given thickness of river ice. Data collected will also be used as a base of comparison for later studies related to modifying bows on watercraft for winter navigation.

Much of what is already known about ice cover can be attributed to the work done by Dr. W. F. Weeks, a geologist who worked with other CRREL scientists in ice physics studies during the voyages of the S.S. Manhattan tanker-icebreaker. These voyages were conducted during two successive winters to test the feasibility of opening a Northwest Passage through the ice cover of the Canadian Archipelago and Arctic Sea.

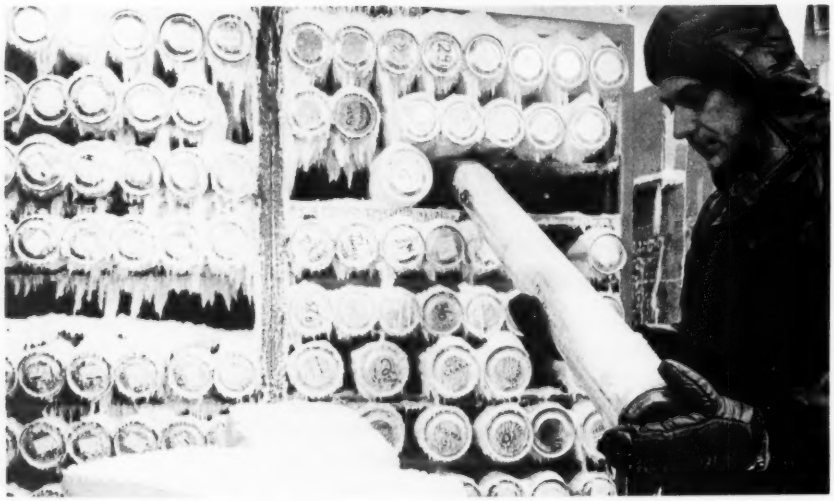
Dr. Weeks' measurement of the stresses that pile up gigantic ice pressure ridges and the behavior of the sea ice found in the arctic area provided other CRREL scientists with knowledge that can be applied to cold weather navigation of inland waterways. Among the pressure ridges encountered, Dr. Weeks commented, the highest measured ridges were over 30 feet.

The Manhattan voyages proved that icebreakers can be designed with enough power to open channels in the thicker sea ice of the Arctic. But technical feasibility doesn't guarantee the benefits would be worth the costs to develop that capability for inland waterways such as the St. Lawrence Seaway and upper Mississippi systems.

The volume of complex problems solved by CRREL's professional staff belies its small size. Slightly over 250 in total number, the CRREL staff is divided into four divisions. About half the staff is assigned to the Research Division under Dr. Kay F. Sterrett and the Experimental Engineering Division under Kenneth A. Linell, both of whom share direction of



The depth of thaw induced by removing protective surface vegetation varies with the amount of insulating matter removed.



Research geologist Dr. Chester Langway, Jr., removes a tube containing an Antarctic ice-cap core sampling from its frozen storage rack inside one of the subzero cold rooms at CRREL's Hanover laboratory.

CRREL's research efforts for the commanding officer and director, Col. Joseph F. Castro. The Technical Services Division provides the laboratory paraphernalia, test equipment and publications support for these research efforts. The Alaskan Division at Fairbanks serves as an on-site extension of CRREL's cold regions research facilities.

The fact that the Research Division contains more scientists than engineers and Experimental Engineering the reverse means nothing more than a convenience of military organization. Besides, it's the problems that usually determine the direction and extent of research, pointed out both division chiefs.

For example, when Mike Bilello began his study of the characteristics of the North American snow and ice cover he found there were no accurate records for his research back in 1964. So he began the arduous task of personally soliciting local residents to help establish a network of reporting stations. Each person who agreed to participate was given a CRREL kit to measure surface depths and temperatures at each of these manned locations. These observations have been continued ever since and are made weekly along with data on surface conditions and reports of first-ice, freeze-over and break-up dates at each station.

Dr. Chester Langway's research of glaciers was similarly limited by the lack of geological samples from the global ice caps. With the aid of Lyle Hansen's Technical Services Division engineers, a suitable ice drilling rig was devised that eventually produced several meters of sub-ice material from both Greenland and Antarctica. The deepest core penetrations measured 1,390 meters in Greenland and 2,164 meters in Antarctica. These core samplings are among those now stored at a sustained -35°F in one of the 24 cold rooms located at CRREL headquarters in Hanover.

The most fascinating aspect of probing into these frozen captives of long ago is best explained by Dr. Langway, Snow and Ice Branch chief, in one of his reports. Dr. Langway wrote that "ice cores are, in

essence, vertical profiles of polar history contained in layered sequence." Frozen versions of the oceans, the Greenland and Antarctica ice sheets are reservoirs of every solid, soluble and gaseous matter ever transported earthward by ancient snowfalls and entrapped by the icy pressures of successive snows. Since further chemical reactions are inhibited by the polar ice cap temperatures, nearly everything remains as it was when first encapsulated.

The approximate scope of this historical span is over a thousand centuries of time based on estimates arrived at by taking stable isotope measurements and carbon-dating the core and from measurements of the bore hole itself. In cooperation with Danish scientists, Dr. Langway's team is also making age-temperature correlations that will attempt to match climatic changes with specific historical periods, including those years in which large volcanic eruptions were known to have scattered airborne ash worldwide.

But volcanic ash is only one of the time-related air pollutants that their investigations are identifying in the entrapped air bubbles within the ice cores. So tiny are these trace elements of the chemical constituents and the ancient compressed atmospheres that the scientists at Hanover have only been successful in identifying them through the use of coupled mass spectrometer-gas chromatograph analyzers and other microchemical techniques.

These analyzers are connected to a data processor for rapid interpretation of information that will eventually permit predictions of future climatic curves. Already CRREL research has established a preliminary relationship between the varying volumes of trace gases and minerals found in the compressed layers of past snows to seasonal temperature fluctuations.

The wealth of data accumulated in the study of cold regions becomes available to the scientific world with the editing and publishing aid of the Technical Services Division of CRREL.

This CRREL generated documentation also becomes available to the public through the National Technical Information Service (NTIS) at Springfield, Virginia. In addition, CRREL sponsors a small staff called the Cold Regions Bibliography Section at the Library of Congress. This section reviews all world literature pertinent to the study of cold regions and produces an annual *Bibliography on Cold Regions Science and Technology* for CRREL.

The Arctic "on-site" capability of the Alaskan Division has been enhanced by the leasing of laboratory facilities at Fort Wainwright and the most famous of this division's test facilities — the experimental tunnel and its attached underground rooms at Fox, Alaska.

The walls of this unique permafrost tunnel exhibit a previously untouched cross section of the underground geological formations and soil compositions common throughout Alaska. The Fox tunnel represents a one-of-a-kind educational tool for CRREL personnel, university faculty members and for others interested in Alaskan geology as a result of the North Slope oil discoveries. It has become one of the biggest attractions for researchers in the Arctic, according to a CRREL engineer.

Not all of what is being learned in Alaska is concerned with the introduction of oil technology to the Arctic or the extension of the navigation season. Much of the knowledge gained by CRREL scientists is being applied to those areas of the globe that do not fall into any definition of a cold region.

For instance, the long search for methods to disperse both warm air fogs and the ice fogs that form at temperatures below -40°F has led to the temporary expedient of utilizing helicopter roter blade downwash to clear obscured runways not only in Alaska, but also far to the south.

And experience gained in seeding supercooled clouds is being applied jointly by the University of Wyoming, the Bureau of Reclamation, CRREL and the U.S. Army Electronics Command. Only the goal is different. Meteorologist Jim Hicks pointed out the difference. Seeding experiments in Alaska are aimed at reducing the "whiteout" type of overcast that blends with the white of the snow cover on the ground. This obliterates the horizon and other visual orientation guides. At Elk Mountain, Wyoming, the resultant precipitation from seeding is intended to build up the winter snowpack on the westerly slopes of the Rockies. This would create an increased spring runoff into the Colorado River Basin which would benefit water thirsty residents well to the west of the range all the way into late summer.

Work with other organizations is viewed as an added opportunity to acquire new knowledge. In fact, outside agency or university contract offers are discriminately accepted on the basis of what long-range informational feedback they can provide toward CRREL's own studies. In essence, each outside offer is examined under a double standard — monetary assistance and potential for advancing the state-of-the-art.

Only through such single minded dedication to its own research goals can CRREL scientists and engineers continue to maintain the leadership of the United States at the forefront of cold regions technology. Only through such dedication can they continue to advance that state-of-the-art for their own satisfaction of scientific accomplishment. That challenge never ends. ■

POWER PLANT SITING:

The Energy-Environment Dilemma

"Almost every morning's newspaper informs us of impending or actual power shortages and brownouts; yet in the same paper we read of opposition to new power supply facilities. Both sides of the conflict have merit, and each of the opposing positions is taken in good faith with a sincere desire to act responsibly."

by E. D. Eaton
Executive Secretary
Committee on Power Plant Siting
National Academy of Engineering

The cooling water requirement of new electric-generation plants is a crucial aspect, and one of the toughest problems to overcome in selecting power plant sites without creating environmental issues. Solution of those issues is complicated by the fact that about 65 percent of the energy consumed in generating electricity is rejected as heat at the plant site.

The complex energy issues demand more than a cursory view. Thus, the National Academy of Engineering (NAE) approached resolution of these problems by viewing the conflicts in a comprehensive manner, concurrently examining the major siting considerations now facing us. To accomplish this, NAE created a Committee on Power Plant Siting (COPPS) that drew its members from the many disciplines and interests concerned with either producing power or protecting the environment.

One result is the COPPS Report developed from a year-long series of studies and meetings. It includes recommendations directed toward resolving key issues on which decisions relating to a national siting policy must be made during the next 15 to 20 years.

The problems that are addressed by the COPPS conclusions and recommendations are discussed in the report, *Engineering for Resolution of the Energy-Environment Dilemma.* The report, published this year, is in two forms, a condensed summary for nontechnical readers,[1] and the full text including technical papers;[2] there is also a separate summary of the recent Forum II conference.[3]

The *Dilemma* referred to in the title of the report is all too familiar now — more and more electricity is needed to run our homes and industries — but the generation of that electricity creates pollution. Thus we are confronted by two major conflicting social objectives.

High levels of energy use may be taken as one measure of national well-being — the means for enjoying a high

1. Available from National Technical Information Service, Springfield, Va. 22151; Call Number: PB 206326.
2. Available from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, D.C. 20418.
3. Available at no charge from the National Academy of Engineering, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

standard of living, for the production of goods and services, full employment and national security. In the United States, use of electricity was about 1,400 billion kilowatt hours in 1970, twice as much as we used in 1960. By 1980, use is expected to double again, and then to double once more in the following decade — estimated use in 1990 reaching 5,300 billion kilowatt hours.

This translates into increasing the installed capacity from the 1970 level of 370 million kilowatts to a 1990 capacity of about 1,260 million kilowatts. To reach this capacity requires the addition of 250 or so new power plants with 500 thousand kilowatts or larger.

But production of electricity is accompanied by production of residues — that is, pollution threatening to degrade the environment and scar the landscape. The residues of steam-electric plants (which will provide virtually all the increased generation) are sulfur dioxide and nitrous oxide and particulates in the stack emissions that come from fossil fuel fired boilers, radio-activity from nuclear fuels and large quantities of heat.

The history of the utility industry is one of continously improving technology and since World War II, generation and transmission technology has advanced spectacularly. In recent years, technology has brought a notable improvement in reducing environmental impacts, especially those from sulfur and particulate emissions. Mitigation of environmental impacts will continue; and there are grounds for confidence in significant improvement during the years ahead as a result of further technological advances. Even so, production of electric power by the technologies available for the next several decades will not be pollution-free, and this is especially true of heat discharges.

Electric generating stations are highly visible sources of smoke and heat, so they are readily identified targets for environmental concern. Almost every morning newspaper informs us of impending or actual power shortages and brownouts; yet in the same paper we read of opposition to new power supply facilities. Both sides of the conflict have merit, and each of the opposing positions is taken in good faith with a sincere desire to act responsibly. Yet more often than not the result has been a stalemate that aggravates the hazards of power shortages and environmental damage.

The situation has become so grave that attempts at legislative remedies are receiving priority attention in the Congress and in a number of State legislatures.

The COPPS Project

In order to make a timely contribution to resolving urgent public problems, the COPPS project focused on issues for which decisions must be made during the next 15 to 20 years. The urgency of these issues precludes temporizing. However, COPPS studies and recommendations sought to avoid foreclosing options that should remain available for dealing with long-term future problems that will be of no less magnitude, complexity and importance to society.

While recognizing that solutions will not be easy, inexpensive or immediate, *the premise which motivated the project is that good engineering can do much to mitigate the conflict; and that the engineering process, to be successful, must use as inputs all of the requirements that must be met, both environmental and in terms of power supply and distribution.* Expert knowledge from biologists, ecologists, health scientists and many others must be used in the engineering process.

Overall planning and coordination of the project was performed by a *Steering Group* representative of environmentalist, utility and independent views, and drawn from government, private industry and universities. Its chairman and vice-chairman were W.D. Lewis, president of Lehigh University, and Denise M. Robinson, board chairman of High Voltage Engineering Corporation, respectively.

A set of four working groups was selected to consider environmental factors from several points of view: *Air, Water, Radiation,* and *Appearance and Land Use.* A *Systems Engineering* working group was also established to investigate procedures whereby all pertinent inputs into siting problems can be accumulated and then weighted in relation to technical, environmental, governmental and public approval requirements. From this, creative syntheses of alternative combinations of technological resources can be composed to meet these requirements. Finally, the alternative which provided the most satisfactory arrangement is selected.

The *Energy and Economic Growth* working group faced the question whether the siting problem could be diminished significantly by slowing the rate of increase in use of electricity. Its study shows that, although meaningful data are scarce and there are many uncertainties, it is difficult to visualize a cessation of growth in total energy requirements during the next two or three decades in the absence of revolutionary changes in our society's structure.

Through these working groups, whose studies are published in the COPPS Report, the major thrusts of the COPPS project were focused on:

- Identifying those conflicts, issues or questions where good engineering can help avoid adverse environmental effects by considering the environmental sciences and value judgements in the process.
- Appraising existing or proposed approaches by reviewing existing methods of setting environmental standards, technological methods of controlling environmental impacts and promising methods of systems analysis and synthesis.
- Identifying areas where further study, research or development seem likely to improve siting methodology.

Through two open discussion meetings COPPS sought wide participation by knowledgeable individuals who are actively involved in these issues. At Forum I, early in the project, about 200 participants identified the problems of power supply and environmental protection that would have to be dealt with in the studies; this inaugurated a continuing highly productive interchange and interaction of ideas and knowledge.

Many of the same individuals, and a good many others in addition, met again 12 months later at Forum II to discuss the conclusions and recommendations of the COPPS Report. The focus of Forum II was on the means for moving ahead toward resolution of the *Dilemma* referred to in the report title.

The COPPS Report

In the preface NAE President Clarence H. Linder points out that, although the COPPS Report does not propose complete or final solutions, it outlines procedures for mitigating precedent-setting problems of power plant siting in which the need for conflict resolution is urgent. While it is not possible in this short article to set forth the range of considerations with which the COPPS project dealt, or even to summarize its report, a few of the salient points may be identified.

Reports of the technical working groups summarize what is now known about impacts on the environment related to bulk electric power generation and transmission, and engineering approaches to their mitigation, along with identification of priority research and development requirements. These technical sections bring together and evaluate the findings in literally hundreds of published and unpublished reports; thus, they are unique critical appraisals of the state of the art for use in professional practice.

Probably of special interest to readers of this magazine may be the report on protection of the aquatic environment, which is the principal recipient of heat rejected from steam-electric generation — now in the order of over 5,000 trillion B.t.u. per year. Potential adverse environmental impacts are considered by ecological zones (oceanic, estuarine, riverine, lakes and reservoirs) and ameliorative measures include short-term and long-term technologies.

From the engineering point of view, there is in-depth discussion of alternative heat dissipation schemes, their effects on water quality and water consumption, and design considerations. Like the other COPPS technical studies this report is intended to aid in application of existing knowledge and experience.

The Steering Group report is directed principally to policy issues. Based in part on the technical studies and in part on broader considerations, some 50 major conclusions and recommendations are addressed to the categories of *general approaches, procedures and organization,* and to *priority research and development.* It is impressive that, for all the diversity of the Steering Group membership, there was substantial consensus on so many significant points. The following are a few greatly condensed highlights of the COPPS Report, exemplifying the Steering Group position.

General Considerations

□ While maintaining engineering integrity and economic feasibility, the construction and operation of generation and transmission facilities should avoid substantial irreversible damage to the environment. A conservative approach should be taken when in doubt, but not to the extent of accepting extravagant claims of environmental hazard at face value. Merely stopping or substantially delaying construction of new facilities is inadequate, considering the already insufficient power supplies in some areas and society's increasing demands.

□ Processes and information now being used to resolve the electric power conflict are inadequate. Approval for the construction and operation of new generation and transmission facilities normally requires too many separate agencies and too much time.

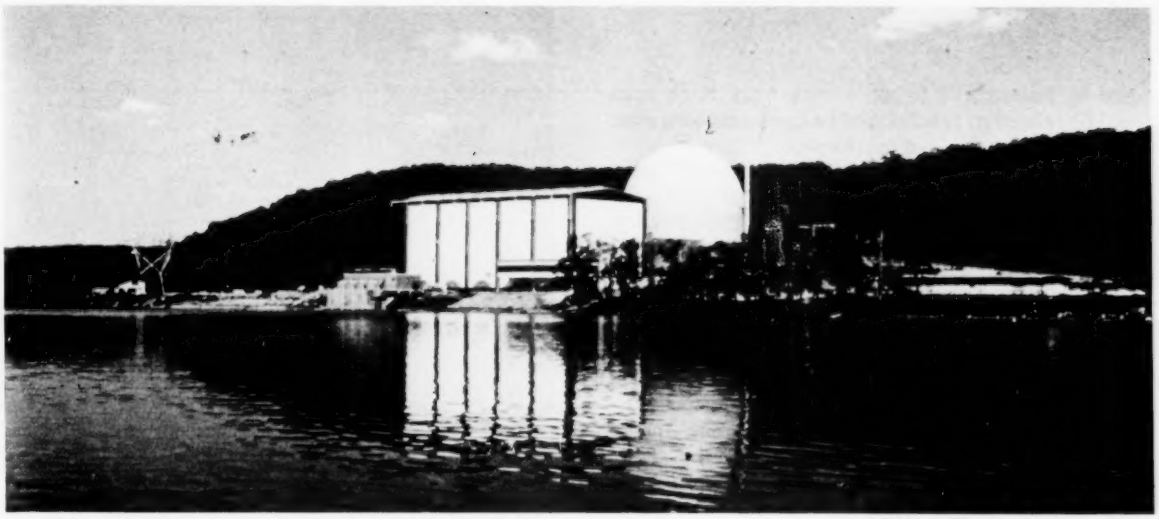
□ Lack of effective channels for consideration of public interest aspects of facility development, and lack of orderly public decision-making are prejudicial to — sometimes foreclosing — effective effort by environmentalists in behalf of their concerns. At the same time, the absence of those channels shackles utilities with serious delays, uncertainties and costly design revisions.

□ Short-range approaches can do much to mitigate but not completely solve the problem during the next decade. The short-term amelioration of the conflict will cost much money and will not completely avoid damages to the environment.

□ With application of new technology, and proper long-range planning and coordination — including the internalization of all costs of production — the concurrent activities of energy production and environmental goals will come closer to reality. The additional costs will necessarily be high, yet they must be economically feasible in relation to benefits.

□ There has not been enough research and development toward better technological methods for supplying adequate power without unacceptable adverse effects on the environment or to provide a basis for rational setting of environmental standards. A considerably expanded and adequately coordinated research and development program can, in due course, lead to a much more complete resolution of conflict. However, because the time from the availability of proven new technology to the actual operation of generating facilities which utilize it is normally about a decade, research and development should not be expected to bring about substantial improvement of environmental conditions in the short-term.

□ Major changes must be made in society's handling of the power plant siting process. It must involve comprehensive engineering that takes into account not only the possibilities of more advanced technology, but also the constraints based upon the best available information about possible environmental effects. The practicing engineer must consider economic factors and he must also provide for integration with the processes of law and public participation. His primary responsibility is to synthesize viable solutions to the problems of producing new electric power capacity without unacceptable environmental impacts. Whereas, the legislator's view should be that timely resolution of power plant siting problems require consideration of all relevant factors (technological, economic, environmental and public opinion) in an integrated fashion from the very beginning.



One of the earliest in existence, the Connecticut Yankee Nuclear Plant at Haddam Neck, Connecticut, has been in operation since 1967. Its 600-megawatts capacity is considered relatively small today.

(Edison Electric Institute Photo)

Procedures and Organization

□ Therefore, certification agencies should be established with final authority to act on power plant siting issues, subject to due process of law, through unified procedures that comprehensively consider all relevant factors and views. This function should be exercised at the lowest governmental level with adequate jurisdiction that can also marshall the required competence.

□ Such agencies must achieve public acceptance and trust; they must understand and respond to the views and interests of all concerned parties; and they must have technical competence to understand relevant factors, including environmental standards.

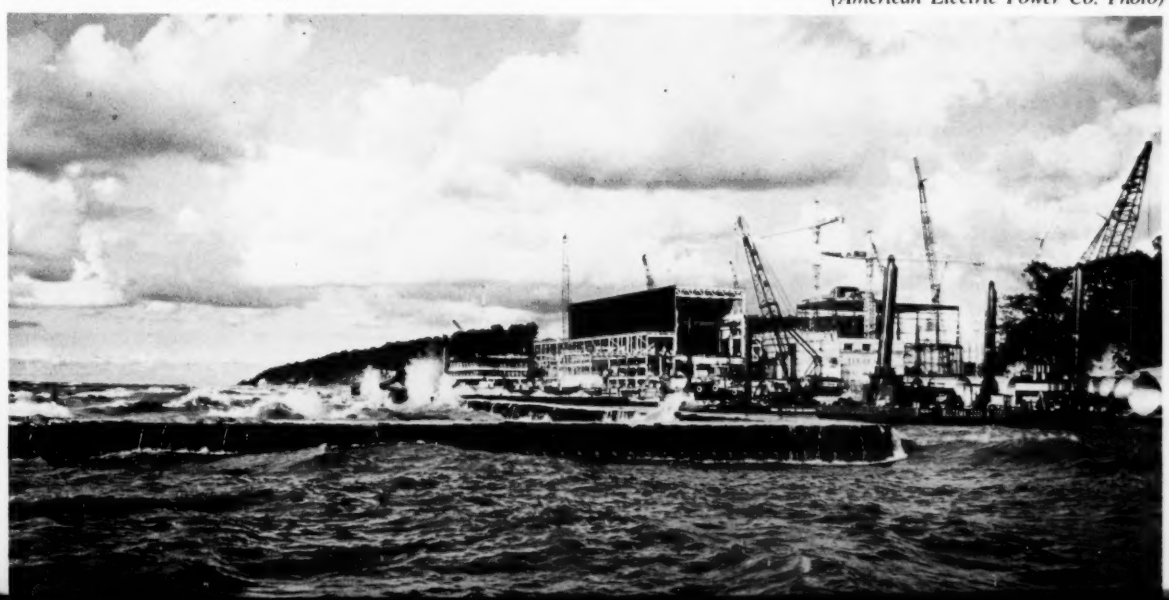
□ That means such agencies must be staffed with competence to deal with economics, power plant technology, and the environmental sciences and standards, plus the ability to employ the processes of cooperation, systematic problem solving and consensus seeking rather than resorting to the adversary process in the courts.

□ The utilities should be charged with the responsibility for proposing solutions to each new requirement for power. It should be up to the utilities to demonstrate that new power generating capacity is required; to consider alternative means to meet this need, and to propose one; to estimate the impact of the proposed facility upon the environment; and to demonstrate that this environmental impact is in conformity with standards. Thus, the systems engineering activities of the power producing utilities must include considerations of environmental impact and control in addition to the power producing technology and economics which have been necessary since the beginning of the electric power industry.

□ Agencies responsible for regulating utilities' finances should acknowledge environmental protection expenditures as proper utility costs. The costs of environmental surveys, monitoring and research as well as the costs of avoiding or ameliorating environmental damage are necessary costs of electric power, and they

Construction of the Donald C. Cook Nuclear Plant begins to take form on the Lake Michigan shoreline in response to increasing energy needs. Both of its 1.1 million-kilowatts units are expected to be operational by 1974.

(American Electric Power Co. Photo)



should be internalized in the service rates. Such costs should be related to benefits, and be consistent with what the public is able and willing to pay.

□ At present, utility planners and even regulatory agencies have only inadequate means for ascertaining the specific nature of public opposition until after initiation of adversary intervention. This deficiency can greatly increase utility costs and forfeit environmental protection. Programs of public information and education about problems and progress in this area should be strengthened.

□ State and Federal standards are technically inadequate as a basis for planning and design. Environmental concerns and standards based upon them are changing rapidly with acquisition of new information. Additionally, in many areas there is disagreement in value judgments for which there is no accepted method of resolution.

□ Environmental criteria and standards set upon power plants should specify the end results to be obtained but should not limit options by regulating how these results should be reached. In furtherance of this, present and prospective environmental standards should be examined to assure their technical validity and feasibility.

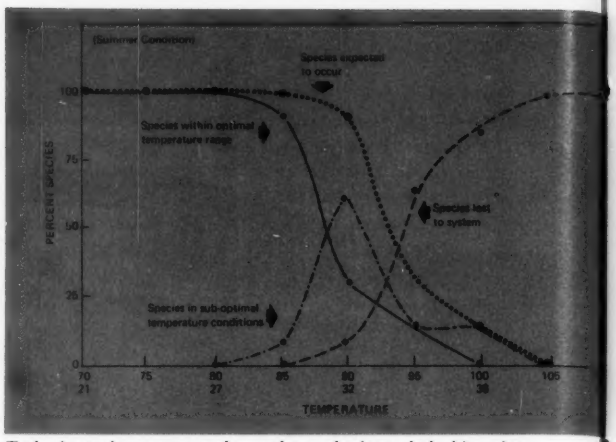
□ The process of environmental standard setting should be strengthened by the institution of a network of monitoring stations, including ones established at power plant sites prior to construction and continued throughout operation at an appropriate level. This should be complemented by a national bank of information about environmental standards, impacts and management.

□ As understanding of environmental effects and their control expands, increasing efforts at establishing rational bases for trade-offs between environmental impacts and dollars should be made. Evaluation of benefits should provide estimates of the costs of successive increments of power supply or environmental protection.

□ Because of the expectation that new technology and understanding will improve the ability to reduce adverse environmental impacts, engineering decisions should be made so that paths to more beneficial options in the future will be kept open.

Priority Research and Development

In making recommendations on priorities for R&D, the Steering Group said, "We believe that the R&D is needed over the whole range of knowledge to be used in setting standards for electric utilities and in making engineering decisions to minimize impact on the environment. Because we must rely on the scientific and engineering knowledge we already have for standards about to be set and for siting decisions of the next five years, the . . . recommendations are directed to problems that extend beyond that time span. It is urgent that R&D on these priority subjects be intensified or commenced now to provide for the future, particularly for the period five to twenty years from now."



Today's engineer must rely on the ecologist to help him plan new power plants. As illustrated above, the effects of adding heat to water reduces the diversity of biotic species within an aquatic community. The initial effect is a short-term increase in weight and quantity among some species, such as a certain group of fish. However, the overall ecological health of the community deteriorates as other species, such as the plankton forms of fish food, eventually disappear above certain temperature conditions.

That range is so extensive and the R&D needs are so numerous and diverse as to defy summarization. In the report, even though the identification of priority R&D needs is stripped down to little more than terse labels for complex subjects, it still fills a number of printed pages. The approach taken is based on the following principles:

□ The aim of the R&D program should be development of the needed competence in electric power generation and transmission and related environmental protection. This requires an enlarged program of R&D that will extend and deepen knowledge of fundamental processes; organize relevant scientific and technical knowledge and other information to facilitate its availability and use; and develop applications of scientific and technical advances to the stage at which they can be put into use.

□ Because substantially increased annual expenditures will be required, the funding of R&D activities should be through a combination of support by those Federal and other public agencies concerned with either energy production or the environment, plus an increase in direct funding by the utilities that should be encouraged by legislation permitting them to recover such expense.

The COPPS project involved a large number of people who are actively engaged in various capacities in the diverse aspects of the energy-environment dilemma, and the report has had extensive distribution. While the Committee on Power Plant Siting terminated with submission of its report and the Forum II meetings, frequent reference to the COPPS recommendations and technical studies are being made by legislators, regulatory officials, research workers, and practicing professionals in utility and environmental fields. This lends support to the appraisal that the COPPS project demonstrates how good engineering can aid in resolution of public issues that are strongly conditioned by technology. ■

N_2 → Threat to Pacific Northwest Fisheries?

by Hugh A. Smith, Jr.

No one would normally conceive of fish suffering from the "bends." Yet the symptoms of what has been called "gas bubble disease" in the Pacific Northwest show distressing signs of similarity to the classic affliction of deep sea divers.

The similarity comes from the severe overdose of nitrogen in the body that characterizes both ailments. The dissimilarity is that the "bends" comes from the effect of rapid depth changes on a diver's body, while "gas bubble disease" in fish can also occur from merely swimming near the surface of supersaturated waters.

Few people really believed a hazard of this type could exist in the major rivers of the Pacific Northwest prior to 1965, when some of the fishery agencies in the area started testing for N_2, nitrogen gas, in the water above and below some of the dams on the Columbia and Snake Rivers. By 1968 there were definite indications of this environmental threat and studies were started to determine the scope. But then "gas bubble disease" has been a recognized problem for years at fish hatcheries using spring water supplies often supersaturated with nitrogen.

The author is a hydraulic engineer in the North Pacific Division of the Corps of Engineers.

External symptoms of "gas bubble disease" are pointed out on a dead fish taken from the Columbia River. This strange malady affecting the valuable salmon and steelhead fishery of the Pacific Northwest may be linked to nitrogen supersaturation of the water.

The association of this hazard with the dams along both rivers was eventually traced to the fact that large amounts of air were being drawn down into the stilling basins below each spillway as the heavy spring flows were being spilled over each dam. The amounts of air entrained and then dissolved in the water produced a saturation level well above normal during the peak spill periods. And the high levels of gas content in the water can cause serious damage to fish populations.

It was quite a surprise that such a problem should have occurred despite the unprecedented application of engineering and biological talents over several decades to preserve these very same fishery resources. Years of engineering talent had been spent originating concepts such as fish ladders and elevators — concepts created to accommodate the primal urge of the salmon and steelhead to migrate seaward as juveniles and return as adults to spawn in the same upstream gravel beds where they had been hatched three or four years earlier.

Supersaturation Effects

Fish swimming up and down the Columbia and Snake Rivers extract the dissolved gases from the water in their gill structures and transfer the gases to their body tissues through the blood stream. These gases remain dissolved as long as the fish remain under similar conditions of pressure and temperature. But when the fish move to the lower pressure of shallower water or swim in the higher temperatures at the surface long enough, the dissolved gases in the blood and tissues try to adjust to the changed condition by returning to a gaseous state. The resultant gas bubbles can kill or damage the fish by blocking their blood vessels.

There's still a great deal to learn about the capability of different fish to accommodate to and recover from varying levels of supersaturation over various periods of time. However, existing test information shows possible danger to fish in the upper six feet of water when the gas concentrations exceed 120 percent of saturation. And it has been demonstrated that fish remaining in supersaturated surface waters will also suffer when the unstable dissolved gases in their bodies eventually revert to gas bubbles.

Juvenile members of the salmon family generally migrate seaward in the top 15 to 20 feet of water, meaning that a substantial number may be exposed to dangerous conditions during the hundreds of miles traveled between the spawning grounds and the Pacific Ocean.

Although adult members generally swim at deeper levels in their upstream migration, they still have to pass through relatively shallow fishways for several days in order to cross the dams in the fish ladders. Thus adults are also exposed to dangerous surface water conditions during the spring and early summer high water period.

Why Water Becomes Supersaturated

The explanation of why the dissolved air content of flowing water can be changed by the operation of a spillway needs to be prefaced by a brief review of physics and chemistry. So let's start with exposing a liquid to a gas at a known temperature and pressure. Given this set of circumstances the gas molecules will diffuse into the liquid until a condition of equilibrium exists. Once equilibrium is attained the liquid is said to be 100 percent saturated with the gas at that particular pressure and temperature. But if the amount of gas in the liquid exceeds the equilibrium quantity for a given temperature and pressure, then we can say the liquid is "supersaturated" with the gas.

If we substitute water and air for the liquid and the gas, and bear in mind that air is mostly nitrogen (78 percent) and oxygen (21 percent), we're actually saying that water exposed to a given pressure and temperature will contain specific amounts of dissolved nitrogen and oxygen in a state of equilibrium. Since early biological evidence indicates that nitrogen is the culprit gas, the situation in the Pacific Northwest has become known as the "nitrogen problem," although it might better be described as the "dissolved gas problem."

Supersaturation of a liquid already in a saturated condition can be caused by a reduction in pressure or increase in temperature. A good demonstration of the effect of a pressure change on a dissolved gas is opening a bottle or can of soda pop. As soon as the top comes off the internal pressure reduces to atmospheric level and the dissolved carbon dioxide gas begins to bubble out. If the container remains open long enough, the gas eventually equilibrates at atmospheric pressure and the carbonated beverage begins to taste "flat."

To simulate the effect of temperature change observe a pan of water heating on the stove. Long before the water reaches the boiling point, bubbles begin rising to the surface. We're actually witnessing dissolved gas coming out of solution in order to return to a condition of equilibrium as the water temperature increases. Obviously, the warmer water will not hold as much dissolved gas.

The flow released over a spillway at a dam produces a reversal of the above examples, resulting in an excess of gas in the downstream water or a supersaturated condition. Air entrained and dissolved at great depths or pressures in the area below the spillway can produce significant supersaturation of the downstream water. This water is never given an opportunity to scrub itself of the excess gas concentration through turbulence-induced contact with the air due to the following reasons.

First, the supersaturated river never gets a chance to fully return to equilibrium between the stair-stepped hydroelectric dams because of the relatively deep, slow-moving flow between the lakes behind each of the downstream dams. (See figure 1.) Secondly, although some release of excess nitrogen does occur between dams, the river is recharged from the spillway of the next downstream dam, so that the water remains supersaturated all the way to the sea. (See figure 2.) Shortly after the spill operation ceases, however, the river returns to its normal level of saturation.

Nitrogen supersaturation is just as likely to occur naturally if air is entrained and dissolved in rapids or waterfalls. This natural occurrence also requires fast moving shallow flows to expedite the release of the excess gas back into the air.

The Columbia River Basin

To understand the importance of the seasonal variations in flow, it's necessary to understand the nature of the Columbia River Basin. This 259,000-square-mile basin has wet, relatively mild winters and warm, dry summers. Upstream from Bonneville Dam most of the precipitation occurs during the winter in the form of snow. The Columbia River begins to rise late in March as the accumulated snowpack begins to melt and the river normally peaks in late May or early June. The flood hydrograph shows a prolonged high-water period of 60 to 120 days during which heavy spilling occurs at most of the dams along the river. (See figure 3.)

Complete regulation of the river flow will probably never be realized since the system of headwater reservoirs will have only 40 million acre-feet of available storage by 1973 and the yearly runoff at Bonneville Dam averages about 142 million acre-feet. The 40 million acre-feet capacity will be reached with the completion of the Libby, Mica and Dworshak Reservoirs next year.

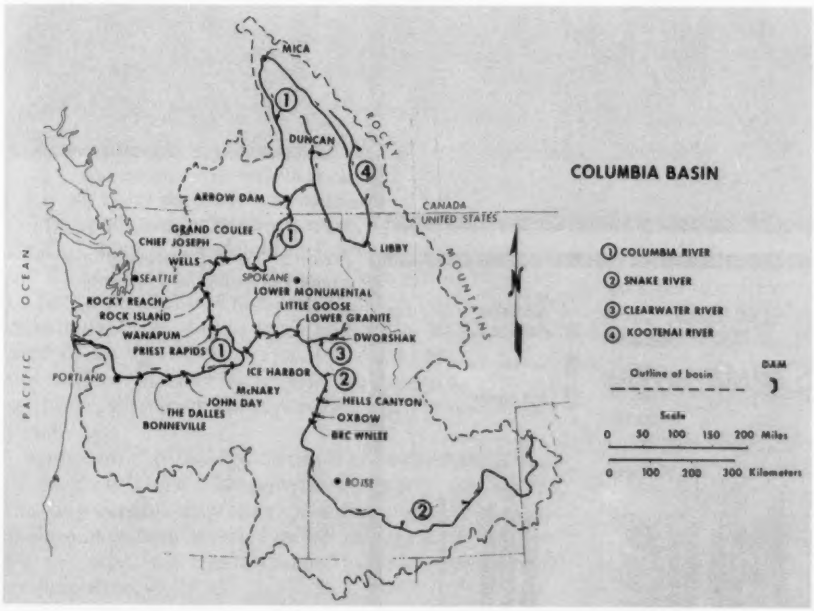
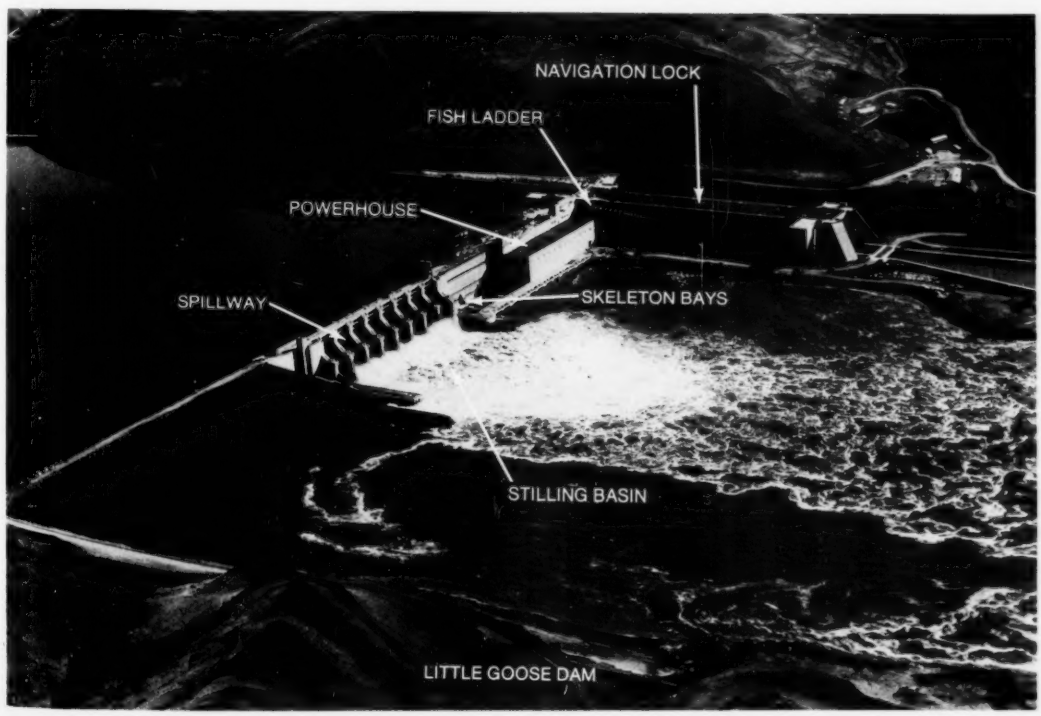


Figure 3. The melting snowpack runoff draining from the headwaters annually creates a flood peak during late May or early June.

The 1973 and 1974 runs will reflect the influence of the two newest dams on future fish migrations. Lower Monumental was completed in 1969, Little Goose was completed in 1970.



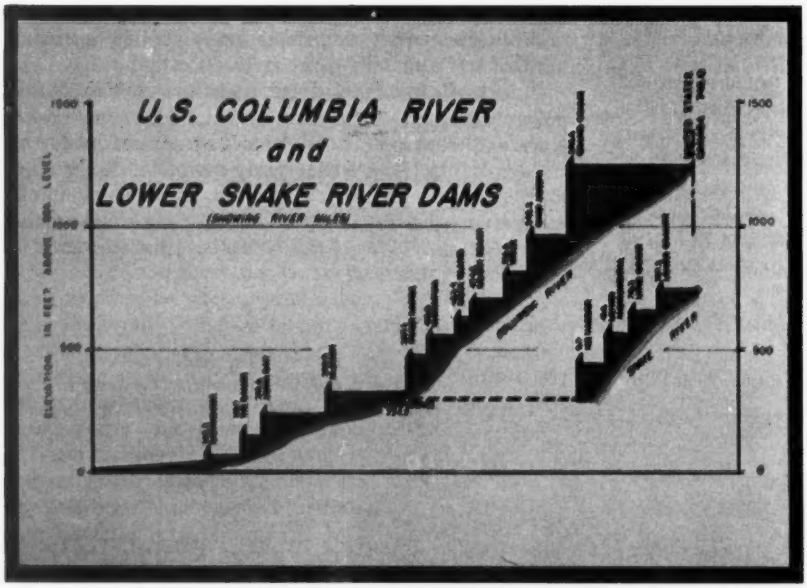


Figure 1. The stair-stepped series of dams hinders large releases of entrained nitrogen gas before the water reaches the next spillway.

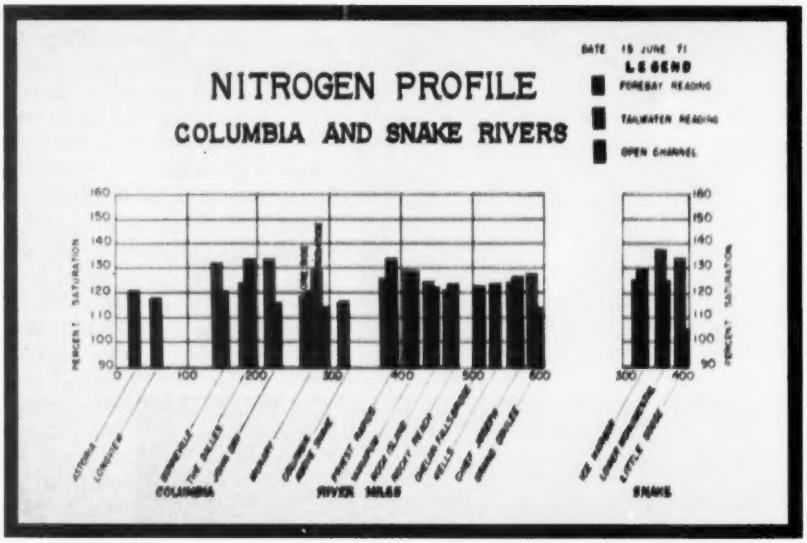


Figure 2. Typical nitrogen profile during the spring-summer spill.

The Anadromous Fish Runs

An anadromous fish ascends the rivers from the sea for breeding. The Pacific salmon and steelhead spawn in the fresh water rivers of the Columbia River Basin. After migrating to the salt water of the Pacific Ocean for part of their life cycle, they then return to the same fresh water rivers to spawn. The steelhead trout and shad may spawn more than once; but the Pacific salmon dies after spawning.

The heaviest fish runs coincide with the spring and early summer high water conditions that produce the supersaturation below each dam. In late March or early April, the spring chinook salmon start moving up the Columbia toward the headwaters where they hatched. They are followed by the summer chinook run starting in June, the shad and sockeye in June and July, the major steelhead run in July and August, and the coho and fall chinook salmon from August through November.

The early spring run fish are generally headwater spawners that journey more than 500 miles up river, while the later runs spawn in the lower reaches. As the adults move upstream, the "wild" juveniles start to migrate downstream and are joined by over 100 million juveniles released from State and Federal hatcheries along the river. These anadromous fish are the lifeblood of a tremendous fishing industry conservatively estimated to have an annual value of $26 million. Ocean trolling landings of 11 million pounds and commercial landings of 10 million pounds in the rivers were recorded in 1970, not to mention the sports catch of 300,000 fish at the mouth of the Columbia and tens of thousands more caught between the mouth and headwaters as far away as Idaho.

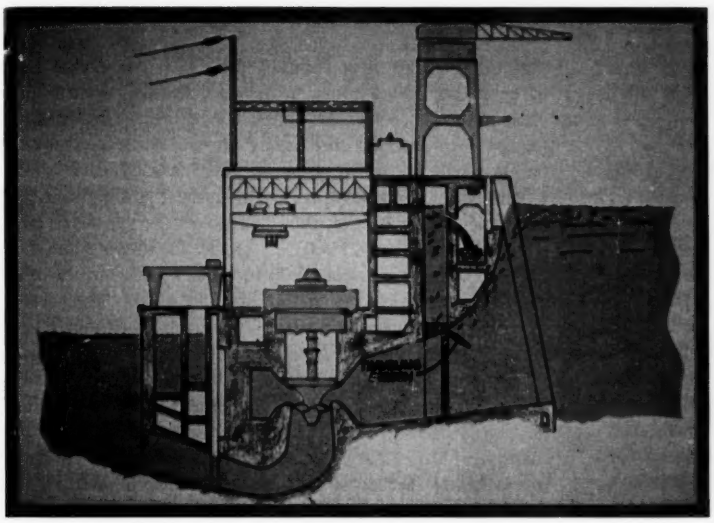
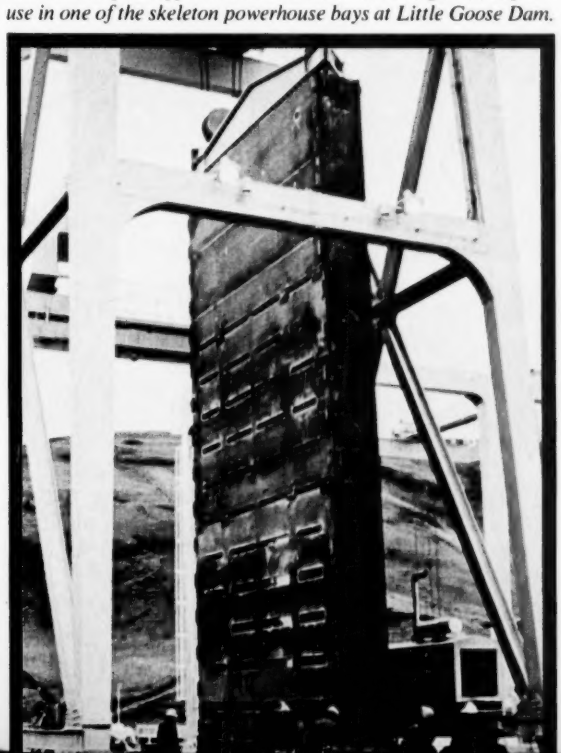


Figure 6. A representative cutaway shows a travelling screen deflecting downstream migrating juveniles into a fish channel at a typical dam. The trapped fingerlings are then trucked to a point below Bonneville Dam on the Columbia.

The anadromous fish are present from the mouth of the Columbia to Chief Joseph Dam and all the way up the Snake River to Hells Canyon Dam. All of the dams on both rivers below Chief Joseph and Hells Canyon are essentially "run-of-the-river," some with an operating head of up to 100 feet. This means that seasonal high fluctuations in river flow must be released over the spillways, since such dams provide only a minor storage capability.

Upstream fish passage facilities are provided at each of the dams along with powerhouse bypass systems for the downstream migrating juvenile fish. About $300 million have been invested in fish passageways, hatcheries and other features associated with maintaining the existing fishery.

This 90-ton prototype "slotted" bulkhead is being readied for use in one of the skeleton powerhouse bays at Little Goose Dam.



Impact of Supersaturation

The National Marine Fisheries Service (NMFS) studies of supersaturation along the lower Snake River between 1969 and 1971 concluded that: "The recently completed Little Goose and Lower Monumental Dams on the Snake River have seriously impaired the 1970 outmigration of juvenile chinook salmon and steelhead trout."

In their conclusions NMFS personnel estimated that the survival rate may have dropped to 30 percent, which they explained as a possible result of "prolonged exposure to high levels of supersaturated nitrogen in the Snake River." NMFS also concluded that loss of steelhead from the Snake River may be as high as the 70-percent-chinook loss.

But in 1971 the NMFS reported survival of juvenile chinook in the Snake increased 20 percent and estimated the overall 1971 survival rate at 48 percent. No precise statement was made on juvenile steelhead because of the behavior difference among various stocks, but the NMFS survival estimates of two hatchery stocks indicated substantial losses.

Returning chinook runs during 1972 will consist of the juveniles that migrated seaward in 1970, when nitrogen conditions supposedly were at their worst according to NMFS studies. The same applies to the 4- and 5-year-old steelhead.

This year we're also beginning to see the return of adults whose parents were subjected to the heavier nitrogen conditions added by the John Day Dam's first year of spilling. Subsequent 1973 and 1974 runs will reflect the effect on both seaward migrants and returning adults of the recently completed Lower Monumental and Little Goose Dams.

Laboratory tests conclusively demonstrated that it takes about a week of exposure in surface waters to kill migratory size juvenile salmon at 125 percent of saturation. Correspondingly less time is fatal at higher concentrations of 135- to 140-percent nitrogen supersaturation. But the real difficulty in the laboratory is

determining what really happens in an actual stream. Even though the fish studied passed through high nitrogen content water on the way to the ocean, 1971 returns of certain species of adult fish were somewhat higher than average. In other words, the drastic forecasts on fish losses may not occur.

Measures Under Consideration

The physical characteristics of the river flow, the periods of fish migration and the fluctuating power demands have all worked to severely limit available solutions. This means the Corps must develop a comprehensive and possibly radical remedial program. Some of the measures currently being considered include regulating reservoir flows, passing water through both operating and skeleton unit bays, preventing deep plunging water spills by deflecting them with "flip lip" additions to the spillways and transporting fish collected upstream around the entire system of downstream dams. Here's how the above measures are supposed to work.

Limited nitrogen supersaturation control was achieved during the 1971 spring runoff through a modified operation of the entire reservoir storage system on both the Columbia and Snake Rivers and revisions in the operation of specific dams. This plan combined water storage with reduced loading of selected turbines and transfer of the excess power produced in order to curtail spill for one week along the lower portion of the Columbia River. This respite permitted State and Federal salmon and steelhead hatcheries to make their annual downstream releases of about 40 million young fish into waters that were relatively low in nitrogen content. Followup testing indicated that the bulk of these fish were able to migrate into the Columbia estuary before it became necessary to resume heavy spilling.

It is obvious it would be desirable to maintain full turbine load and full powerhouse flow to reduce the spill during the spring freshet period. There is no contribution to the nitrogen problem from the powerhouse bays, since the turbine unit flow releases do not entrain air as the spillway does. However, the system's electrical capacity is sized to meet maximum demand for the heavy use normally expected in the Northwest during midwinter, when natural flows are lowest. But the power demand during the May-June freshet period is only about half that amount. Thus, many turbine units have no load and cannot be operated during the heavy freshet flow, even though this is when the migratory fish population is at its peak in the river.

Skeleton Bay Diversion

Hydraulic model studies by the Corps at its Bonneville, Oregon hydraulic laboratory developed a skeleton bay diversion technique that should help reduce the required spill during the spring freshet period. Skeleton bays are partially completed powerhouse structures that will house additional generating units in the future. Meanwhile, these open bays can bypass water through the dam and correspondingly reduce spillway flow. Since only three of six powerhouse units were initially installed at each of the three lower Snake River dams (Ice Harbor, Lower Monumental and Little Goose), this technique is particularly suited to these three locations.

The model studies developed multi-orifice bulkheads necessary to dissipate the energy of the flow entering each powerhouse structure. Three of these placed in each skeleton bay, according to model tests, would make each bay capable of releasing about 21,000 cubic feet of water per second (cfs) with no entrainment of air. This is about the same volume of flow that would be passed through operating turbine unit bays. A prototype installation of these bulkheads was tested in one bay at Little Goose during the 1971 freshet season and proved the success of this effort. There was no increase in nitrogen levels below the dam according to NMFS testing. The bulkheads designed for the Little Goose project have 60 rectangular, nozzle-shaped orifices 4 to 6 inches high by 3 1/4 to 4 1/4 feet wide. Sometimes called a "slotted bulkhead", each prototype is 52 feet high by 23 feet wide and weighs over 90 tons. (See figure 4.)

This demonstration stimulated tremendous effort by the Governors of Washington, Oregon and Idaho, along with concerned environmental and fishery agencies, to obtain Federal funding for installing slotted bulkheads for use as skeleton bay diversions at all three lower Snake River projects.

Thus, we were able to apply some $12.2 million in additional funds obtained from Congress to complete this work prior to the 1972 freshet period. With this construction now completed it is estimated that during an average freshet season the spill duration would be reduced from about 80 days to less than two weeks and the spill amount from 100,000 to 30,000 cfs at these three dams.

Unfortunately, the identical skeleton bay diversion scheme cannot be adapted to the four lower Columbia River Dams — Bonneville, The Dalles, John Day and McNary. The reason is that there are no skeleton bays available at Bonneville, The Dalles and McNary Dams. However, continuing hydraulic model studies now indicate that the four skeleton bays at John Day Dam, in spite of more restrictive geometry, may be equally effective as those now being used on the lower Snake River.

Energy Dissipation

Another element of the nitrogen alleviation program being tested by the Corps concerns a complete reversal of normal design criteria used in hydroelectric developments. The intent of this unique approach is to release a maximum flow through the turbines with a minimum generation of electricity: in other words, a deliberate attempt at "inefficient operation." Even in the absence of a power demand, this method could permit maximum flow through the turbines that would otherwise be released over a spillway. Without prior dissipation of the flow's energy a maximum flow at low load conditions is not physically possible.

To test this concept three of the slotted bulkheads designed for the skeleton bay diversion were placed in the intake slots of one of the turbines at Little Goose Dam last July. This short-duration feasibility test showed that reducing the effective hydraulic head at the intake passages resulted in a large reduction in power output. The Kaplan-type unit used generated only 7.5 megawatts from a flow of approximately 20,000 cfs. Yet this same unit is actually capable of producing 155 megawatts under the full hydraulic head available.

Based on this observation it may be feasible to place slotted bulkheads into the intakes of those powerhouse units not required to meet power demands during the spring freshet period. Then remove them for the rest of the year to permit normal, efficient operation.

More comprehensive testing this year should answer the nagging question whether continued "inefficient" operation would eventually damage the turbines.

Flip Lips

A further means of reducing nitrogen supersaturation centers on the spillway-stilling basin area at each dam where the entrainment of air occurs. The basic concept involves deflecting low to moderate spillway flows along the downstream water surface with concrete deflectors called "flip lips" instead of letting the water plunge to great depths. These deflectors could be used at nearly all spillways in both the lower Columbia and Snake Rivers. (See figure 5).

Model tests of this concept showed promising results. But since we could not scale the extent of nitrogen saturation in a model, two full size prototype deflectors were constructed (one at Bonneville and one at Lower Monumental) earlier this year to collect test data during the 1972 freshet season. Analysis of this test data will tell us whether or not to go ahead with building more deflectors.

Fish Transportation

Coupled with these other techniques, the Corps is also continuing experimental transportation of fish around the nitrogen problem areas. For several years before the emergence of the problem, NMFS studies have been concentrating on effective methods of deflecting juvenile fish from the turbine intakes, and then trapping and hauling them to the sea in tank trucks. The effect of juvenile transportation on the homing instinct of the returning adult fish is possibly the most important portion of these tests.

If successful, this fish hauling program can mitigate both known losses in the turbine intake passages and unknown numbers lost to predators in the reservoirs, while reducing their exposure to nitrogen supersaturation. It offers a contingency method of protecting the fish runs while better ways of eliminating the basic problem are being devised.

Over $1 million have already been spent to support NMFS testing of a prototype deflection, trapping and transport system at Little Goose Dam. NMFS installed three large complex, rotary traveling screens in the intakes leading to one of the three turbine units at this dam. (See figure 6.) Then NMFS marked the fish trapped at Little Goose to compare the return rate of those hauled to sea with their control groups. These control groups were released below the dam and allowed to migrate seaward in the normal manner.

The 1971 total was some 380,000 juvenile salmon and steelhead trapped, transported or otherwise handled. (About 90 percent of the fishes entering the turbine intake can be deflected into the collection system when the screens are operating.) Although these fishes were safely hauled to a point below Bonneville — the last dam seaward on the lower Columbia River — a meaningful evaluation of this test cannot be made until these juveniles return as adults in the next few years.

Water Quality Standards

The Northwest Region of the Environmental Protection Agency published a report entitled "Nitrogen Supersaturation in the Columbia and Snake Rivers" last July which brought together available information on the biological effects of nitrogen supersaturation on fish and causes of the problem. This report also presented a series of recommendations for a regional strategy of abatement and prevention.

Included was a recommendation that Oregon, Washington and Idaho take immediate action to establish water quality standards in which the maximum allowable dissolved nitrogen concentration would be set at 110 percent of saturation. This recommendation was unanimously supported by Federal and State fishery agencies and endorsed in a joint resolution at a tri-state Governors meeting last November.

Hearings and other followup action by the environmental control agencies involved may establish this level as the current standard, at least until more information is accumulated. Meanwhile, the Corps is participating with the fisheries and environmental agencies in developing a bioassay program. This program should establish the nitrogen damage levels that are necessary for meaningful water quality standards.

Future Prospects

Based on the envisioned structural modifications, improved reservoir regulation, a major increase in headwater storage by 1973, a growing demand for electricity in the Pacific Northwest and other methods of relieving the current nitrogen problem, we feel this environmental situation can be overcome in the near future. This optimistic attitude is fortified by the environmental improvement now being experienced in the Willamette River in Oregon.[1]

1."A River Reborn," *Water Spectrum*, Spring 1971, pp. 33-35.

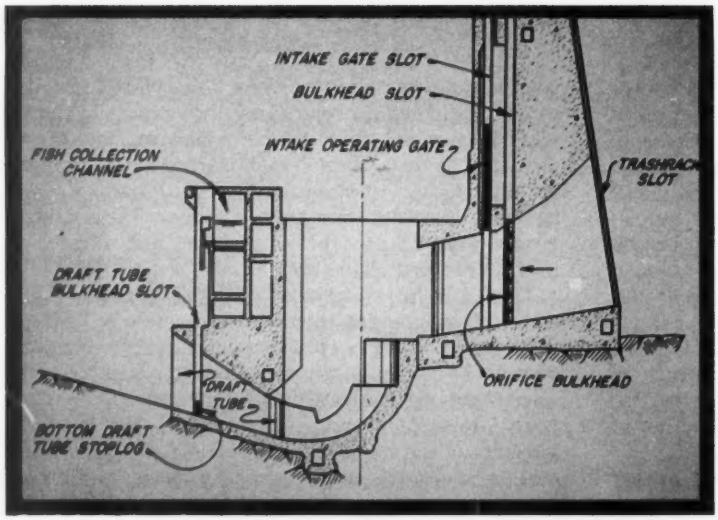


Figure 4. A cross section of a typical skeleton bay shows how water can be diverted through an empty powerhouse bay in the dam instead of being permitted to flow over an adjoining spillway.

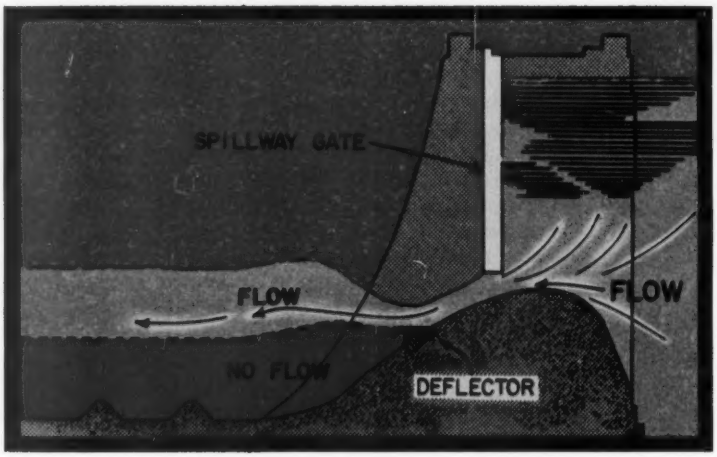


Figure 5. The concept is to reduce the nitrogen supersaturation in the released flow by preventing the water and entrained air from plunging deep into the stilling basin. The preliminary information obtained on the use of these deflectors is most encouraging.

Perhaps the least understood aspect of this nitrogen situation is that the dams involved serve many functions. Each dam represents a multipurpose project carefully engineered to achieve several regional benefits concurrently. However, every project built will cause some change in the environment. In this case it has been the ecosystem within the Columbia River Basin.

The inclusion of fish ladders with power producing and navigation facilities was part of this multipurpose goal when the dams were built. There is no doubt that dams and fish can coexist, but there is still some doubt on the extent of environmental effect of dams on fish survival rates.

Although the Corps does not have the biological staff expertise to either confirm or refute the NMFS staff reports, we hope the dire predictions on fish deaths do not come true. Early indications based on returning adult runs appear to show that the losses may not be as severe as first predicted.

Our optimism is based on the returns for two successive days in late April when the spring chinook runs broke the old 1947 daily record of 14,500 salmon. The new 1972 record count of chinook passing over Bonneville Dam reached 19,241 on the 26th of April, beating the old record by more than 4,000. On the 27th, the count was over 16,000, making two consecutive days exceeding the old record. Furthermore, the daily counts on the 25th and 28th were both almost identical with the old 1947 record itself.

The spring chinook salmon count at Bonneville was approximately 155,000 as of the first of May this year. For comparison, the preceding 33-year average as of that date was 46,000 and the average for the entire spring run was 88,000. With 31 more days of counting, it appeared almost certain even then that a new record would be set for the spring chinook run. The record set in 1969 was 173,600. In fact, commercial harvesting began earlier than usual this spring after the record numbers of chinook had been allowed to escape over Bonneville.

Since these new records only represent the spring chinook run, we still don't know the effects of nitrogen supersaturation on all the runs that occur annually. We expect to learn the full truth as the adult fish return to the river in the next few years.■

Events, Deeds & Deliberations

The First Four

In an important first step toward development of a comprehensive environmental information system, the Corps of Engineers recently initiated four pilot environmental reconnaissance inventories and in the Charlestown Engineer District, which generally parallels the State of South Carolina. The results are scheduled for completion by this December.

These pilot studies by the Corps are intended to identify natural and manmade *resources, amenities* and *problems* which are widely regarded as being of statewide or national significance; particularly those about which the public often expresses concern, and over which environmental controversies frequently arise.

The determination as to whether any specific resource, amenity or problem should be included in an inventory will be based upon the combined knowledge, judgments and preferences of the following: Federal and State resource agencies, acknowledged authorities, environmental-conservation organizations and the concerned public. Thus, each inventory will provide a selective overview of environmental values and problems within a specific region.

This information will be particularly useful in the early stages of planning — for both comprehensive and special studies — and as an aid to the consideration of environmental impact statements and permit applications.

These inventories are being conducted to represent the values, not of the Corps, but of others that are particularly knowledgeable as well as concerned about the environmental values of their own areas. To maintain these values, this information will be collected on a statewide basis independent of any particular Corps study.

Inventory results will be compiled and reproduced in individual atlases containing maps, overlays and supporting information for each State. The supporting information will include bibliographical data and descriptions of the environmental features that are mapped.

For specific water resource projects, the type of inventories initiated in the pilot studies will provide only part of the total information required. Such cases call for in-depth, project-oriented inventories consisting of environmental information developed in sufficient detail to support basic planning, a cause-effect analysis and full evaluation of the specific area under investigation.

Such an in-depth inventory would be conducted by the Corps for all future studies. In addition baseline investigations and monitoring of selected environmental parameters would be performed on particular projects. The former would establish a set of base conditions before alteration of the environment, the latter would define changes in such conditions following construction. The dual objectives of these activities would be to aid that project's operation and maintenance and to provide feedback for use in future planning design and construction.

License Fee Challenges History?

Wisconsin's $3.25 boat license fee is being challenged as an infringement of a national right bestowed on American citizens in the Ordinance of 1787, enacted to encourage settlement of the Northwest Territory. A State circuit court judge contends this modern day fee contradicts the Ordinance's historical provision that waters within the then unsettled territory should remain "forever free."

This unique 15-foot Sawfish, a new-fangled tool acquired by the Forest Service, is named for its awesome array of vertical and horizontal cutting blades used to slice out massive growths of under-water vegetation that eventually destroys a lake. After the lowered cutting blades "mow" the lake bottom, a rake-like attachment pushes the cuttings on shore for disposal.

Pollution Not Permanent

Michigan State University studies indicate that a stream's oxygen level quickly returns to normal when organic pollution is halted. Freshwater ecologist Kenneth W. Cummins reported his research team injected organic materials into a simulated stream while measuring the fluctuation in oxygen content.

Tentative results show that stream turbulence can restore the oxygen content to a level that will support fish life even after severe contamination by acids and compounds that deplete the stream's normal oxygen supply. It will take more studying before these findings can be applied to sewage, farm runoff and other types of organic pollution. ■

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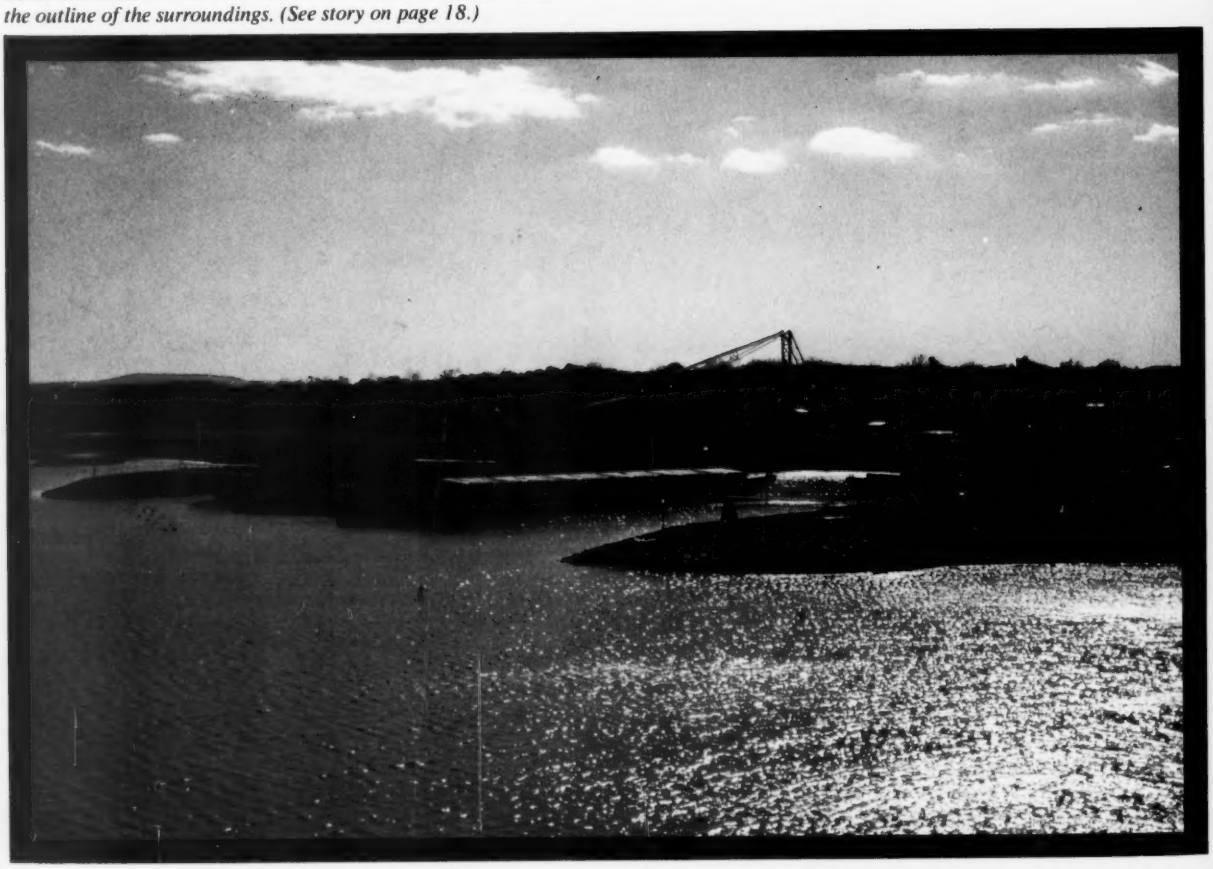
A waterway waits for industrial growth to absorb it into the physical environment such as the case here where coal docking slips take on the outline of the surroundings. *(See story on page 18.)*